

1571/82

SOIL AND ITS PROPERTIES

INSTRUCTIONAL-CUM-PRACTICAL MANUAL





3724

14.1.87

SOVIET UNION
PROCLAIMS





SOIL AND ITS PROPERTIES

Instructional-cum-Practical Manual

S.C.E.R.T., West Bengal

Date

Acc. No.



A. K. SACHETI
(Project Co-ordinator)



राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

October 1985
Ashvin 1907

P D 5E



© National Council of Educational Research and Training, 1985

J.C.E.R.T., West Bengal
Date...14...1...87...
Acc. No...3724...

Rs. 10.45

Published by C. Ramachandran, Secretary, National Council of Educational Research and Training, Sri Aurobindo Marg, New Delhi 110016 and Photo type setting by Rajeshwari Photosetters (P) Ltd., 2/12 East Punjabi Bagh, New Delhi 110026 and Printed at

FOREWORD

The programme of vocationalization of higher secondary education has been accepted by the country as it holds forth great promise for linking education with the productivity and economic development of the country by providing education for better employability of the youth.

In view of the importance of the programme the NCERT is making an all out effort to provide academic support to the implementing agencies in the States. One of the major contributions of NCERT is in the field of curriculum development and in the development of model instructional materials. The materials are developed through workshops in which experts, subject specialists, employers' representatives, curriculum framers and teachers of the vocational course are involved. These materials are then sent for try-out in schools and feedback is collected through questionnaires and through direct contact. The materials are also sent to experts for comment before they are published.

The present manual on **Soil and its Properties** has been developed in the manner described above and is meant for the students studying Crop Production and allied vocations. It is being published for wider dissemination amongst students and teachers throughout the country. I hope that they will find the manual useful.

I am grateful to all those who have contributed to the development of this manual. I must acknowledge also the immense interest taken by Prof. A.K. Mishra, Head, Department of Vocationalization of Education in inspiring his colleagues in their endeavours to develop instructional materials. Dr. A.K. Sacheti, Reader, functioned as the Project Coordinator for the development of this title in association with Dr. A.K. Dhote, Lecturer. They have my appreciation and thanks for planning, designing and conducting

the workshops, for technical editing and for seeing this manual through the Press.

Suggestions for improvement of this manual will be welcome.

P. L. MALHOTRA

Director

New Delhi
October, 1985

National Council of Educational
Research and Training

PREFACE

Ever since the introduction of vocationalization in our school system by several States and Union Territories in our country the paucity of appropriate instructional materials has been felt as one of the major constraints in implementation of the programme and a source of great hardship of pupils offering vocational studies at the higher secondary stage.

The Department of Vocationalization of Education of the National Council of Educational Research and Training, New Delhi has started a modest programme of developing instructional materials of diverse types to fill-up this void in all major areas of vocational education. The task is too gigantic to be completed by any single agency but the model materials being developed by us might provide guidance and impetus to the authors and agencies desiring to contribute in this area. These are based on the national guidelines developed by a Working Group of experts constituted by NCERT.

The present manual is on **Soil and its properties** and is meant for the pupils and the teachers teaching Crop Production and allied Vocations being offered in a number of States. It contains activities (Practical exercises) to be performed by pupils with simple steps to follow, precautions to be taken and data to be obtained and processed. Each activity is complete with objectives, relevant information, behavioural outcomes, evaluation, etc. It is hoped that the users will find them immensely useful.

The experimental edition of the manual was developed by a group of experts as contributors in a workshop held at the Directorate of Extension Education, University of Udaipur, Udaipur, Rajasthan. The same was later circulated to receive the feedback from the user pupils and teachers in the States of Tamil Nadu, Karnataka, Andhra Pradesh and Maharashtra. After a period of one year for the try-out, the feedback was received and accordingly the experimental edition was suitably reviewed and revised through a committee of experts in a workshop held at the University of Agricultural Sciences, Hebbal, Bangalore. The names of the contributors and reviewers are mentioned elsewhere and their contributions are admirably

acknowledged. We are grateful to all the institutions, students and teachers who have used the manual and sent their comments. Dr. A.K. Sacheti, Reader and Co-ordinator of this Project and Dr. A.K. Dhote, Lecturer, Department of Vocationalization of Education deserve special thanks for editing and bringing the manual in the present form. The assistance of all in the University of Udaipur, Udaipur Rajasthan; the University of Agricultural Sciences, Hebbal, Bangalore and the Department of Vocationalization of Education, NCERT is also thankfully acknowledged.

ARUN K. MISHRA
Professor and Head

**Department of Vocationalization
of Education**

New Delhi
October, 1985

ACKNOWLEDGEMENT

The following experts participated in the workshops conducted by the NCERT. Their participation as contributors or reviewers is gratefully acknowledged.

Contributors

Dr. T.N. Chaudhary, Dr. S.N. Sharma, Dr. B.N. Swami, Dr. A.K. Dhote and Dr. A.K. Sacheti.

Reviewers

Dr. Sant Singh, Dr. A.B. Ghosh, Dr. P.B. Deshpandey, Dr. U.S. Sreeramulu and Dr. B.L. Jain.

ABOUT THE MANUAL

Under the programme of Vocationalization of Education about 20 different groups of vocational courses in the area of agriculture have been introduced by nine States and three Union Territories so far. These courses have been running for the last six or seven years. From the very beginning the Department of Vocationalization of Education in the NCERT has been working hand in hand with the State organisations concerned, - through various programmes organised for State officials, vocational teachers, and others. In fact, by now the Department has conducted on-the-spot studies of vocational programme in large number of States, to find out merits and demerits of the programme and to suggest appropriate measure to resolve the problems in 'vocational agriculture education'. These programmes have revealed that there was a great dearth of suitable textual/instructional materials; the need for practical manuals, especially, was urgently felt. The development of instructional materials and the imparting of practical training become even more important when one considers the purpose for which the vocationalization of education programme has been launched. The main aim of the programme is to prepare the pupil for purposeful and gainful employment (wage-earning or self-employment).

The Department constituted a Working Group during the year 1982 to formulate guidelines for developing models for a variety of instructional materials.

Based on the guidelines formulated by the Working Group, Crop Production, which is an important and popular vocational course in agriculture, was selected by the Department for the purpose of development of instructional materials in a phased manner. To begin with, the development of instructional-cum-practical manuals has been taken up.

The content of Crop Production and similar courses offered by the States and Union Territories under different titles was thoroughly analysed and it was felt that seven manuals would be necessary to cater to the needs of the course. The present manual on **Soil and its Properties** is one of them. This manual is intended to help both

teachers and pupils in the study of soil, its analysis and characteristics as preparation for this vocation. While developing the manual, care was taken that it should include the maximum number of Activity Units (practical exercises) so that it can fulfil the requirements of the course prescribed by the States and Union Territories in the Crop Production as well as in other vocational courses.

These Activity Units are essential to develop the required vocational skills in the pupils. The manual explains in detail the 'what', 'why', and 'how' of these Units.

In the manual each Activity Unit has been dealt with under several sub-heads, viz., instructional objectives, relevant information, precautions, materials required, procedure, observations, expected behavioural outcomes and questions.

Before commencing the actual work under any Activity Unit, the teacher should know what exactly the pupils have to learn and do, and should also assess whether they will be able to do that. Therefore, in the beginning, instructional objectives for the pupils should be framed in behavioural terms by the teacher.

In order to acquaint the pupils with the Activity Unit the teacher should provide them with the required theoretical knowledge or information relevant to the activity. This will help the pupils to properly understand the Activity Unit. In other words, the 'what' and 'why' parts of the Activity Unit should be explained in advance by the teacher.

Once the pupils have understood the relevant theoretical instructions, the teacher should tell them about the precautions which are to be taken before and during the actual execution of the Activity Unit. This will facilitate smooth working. The 'how' part of the Activity should be explained by the teacher in the 'procedure' which pupil should follow while performing the Activity Unit.

Under the sub-head 'observations', the teacher should tell what to observe and in view of that the pupil should observe the situation, take readings, note down the temperature and similar other points, under each Unit; these may vary from Unit to Unit. Wherever calculations are required to be done to obtain the results, this should also be indicated under this head or under separate head.

At the end of the Activity the pupil will have acquired certain abilities which should be closely related with the instructional objectives formulated for each Activity Unit. These abilities should be listed under the sub-head 'expected behavioural outcomes'. Evaluation should be based on the abilities acquired and it should be

be listed under the sub-head 'expected behavioural outcomes'. Evaluation should be based on the abilities acquired and it should be done by the teacher concerned.

For evaluating each aspect, the teacher will use a four-point scale, i.e., A, B, C & D, and for each Activity Unit the Grade Point Average can be calculated as indicated below :

Suppose there are four aspects, each carrying equal weightage, and a pupil obtains 2A's, 1 C and 1 D and if A = 4 point, B=3, C=2 and D=1 point; then, based on the grades, the pupil will get 11 points. When the number of points obtained is divided by the total number of aspects examined, it will give the Grade Point Average, which, in this case, is 2.75. The tabular presentation is as under :

<i>Aspects</i>	<i>Weightage</i>	<i>Grades Obtained</i>	<i>TOTAL POINTS (weightage × point-equiva- lent to grade obtained)</i>	<i>Grade Point Average</i>
1	1	A	1 × 4 = 4	= 11/4 = 2.75
2	1	C	1 × 2 = 2	
3	1	D	1 × 1 = 1	
4	1	A	1 × 4 = 4	
			11	

At the end of the Activity Unit, some questions relevant to it are also given. The pupils should write the appropriate answers after the completion of the Activity Unit and teacher should examine them. If required, he should make suitable corrections and give suggestions. However, answers to these questions will not be considered for the purpose of grading.

CONTENTS

Foreword	iii
Preface	v
Acknowledgement.....	vii
About the manual.....	ix
Introduction.....	1
Activity Unit	
1. Soil sampling	4
2. Preparation of soil sample in the laboratory and determination of moisture content in the sample	11
3. Determination of bulk density of soil	16
4. Determination of particle/real density of soil.....	21
5. Computation of pore space in soil	26
6. Mechanical analysis of soil by hydrometer method	29
7. Determination of soil texture by feel method	37
8. Study of a typical soil profile	41
9. Determination of field capacity of soil.....	46
10. Determination of saturation capacity of soil.....	52
11. Determination of infiltration rate of soil	57
12. Study of soil-water relationship	62
13. Determination of soil pH	68
14. Determination of total soluble salts in soil	75
15. Determination of carbonates and bicarbonates in the saturated extract of soil	81

16. Determination of chloride in saturated extract of soil	86
17. Determination of organic carbon in soils	90
18. Determination of available nitrogen in soil.....	95
19. Determination of available phosphorus in soil	99
20. Determination of available potassium in soil	105
21. Determination of gypsum requirement of soil	109
22. Determination of lime requirement of soil	114
23. Reclamation of saline, alkali and saline-alkali soils	118
24. Reclamation of acid soils	126
25. Interpretation of soil test data	132

Appendix

I List of chemicals	141
II List of glass-ware	143
III List of laboratory instruments/equipment.....	145
IV List of miscellaneous items	146
V List of the contributors and reviewers	149

INTRODUCTION

Soil can be visualised as a three-phase system consisting of solid, liquid and gaseous state of matter. The solid phase is composed of (i) mineral matter derived from the weathering and breakdown of parent rocks as influenced by the various processes of soil formation and (ii) the organic components resulting from the accumulation and decomposition of plant animal residues. In addition, an arable (cultivable) soil contains innumerable living organisms, both macro and micro of plant and animal life, the most active and numerous among them being the micro-organisms. The solids occupy nearly one-half of the soil volume and make up the major portion of soil mass. The liquid phase is constituted of water with small amounts of dissolved solids (mainly the soluble salts) in it. The gaseous phase, as compared to atmospheric air is relatively richer in carbon dioxide, due to respiration of soil microbes and plant roots. These phases are not physically separable but are intermixed in such a way that the solid particles are interspersed with pore spaces and capillaries which are filled with air and water. The space occupied by air and water together constitutes about 50 per cent of the soil volume and the two bear more or less an inverse relationship between them. As the volume of water in a soil mass increases due to rain or irrigation that of air decreases accordingly. The reverse is true when water is removed by drainage, evaporation and or transpiration of plants.

Soils vary considerably in their physical and chemical properties because of the nature, composition, distribution and orientation of soil constituents. These result from differences in weathering, mineralogical composition of parent rocks, vegetation, organic matter, activity of soil organisms, and climatic conditions. Various soil physical properties such as texture, structure, bulk density, porosity, water retentivity and water movement are determined by the relative proportion of soil particles of varying sizes (sand, silt and clay), nature and their arrangement.

All arable soils contain variable amounts of organic matter formed from the decomposition of plant and animal residues, which

constitutes an integral part of the soil and is known as humus. Humus and clay are very small sized particles in the range of colloidal dimensions. These exhibit colloidal properties and largely contribute to the physico-chemical behaviour and nutrient status of the soil.

The various plant nutrients (nitrogen, phosphorus, potassium, etc.) in soil occur as ions mainly in three forms namely, ions bound up or complexed within the soil particles, those adsorbed on the surface of the organic and inorganic particles by electrostatic forces of attraction and ions in solution within the soil, known as soil solution.

The soil solution in a normal soil has quite a low concentration of the nutrient ions. The ions adsorbed or retained on the surface of the colloidal particles (colloidal interfaces) are of greater importance as they indicate the potential availability of nutrients to plants. The colloidal particles in the soil are of various size and shape and the ions are held (by electrical force of attraction) on or in the vicinity of the surface with different electrostatic strength of bonding. Soils colloids are primarily negatively charged. Cations like Ca^{++} , Mg^{++} , Na^+ , K^+ etc. held against the negatively charged colloidal particles (inorganic or organic), are distributed in a diffused manner in the soil system and a part of these are exchanged with other cations, some readily, some less easily and the rest with difficulty. This sort of behaviour of soil colloids to exchange cations adsorbed on the surface on the *equivalent basis* (two Na^+ or K^+ for one Ca^{++} or Mg^{++}) is a very important property known as cation exchange and the sum total of the cations thus exchanged is the cation exchange capacity. The cation exchange capacity can be experimentally determined by displacing all the cations from the exchange sites with the help of any other cation and estimating displaced ions. Obviously, a soil which is richer in colloidal constituents (clay and humus) will exhibit a much higher cation exchange capacity than a sandy soil or where there is less of organic matter.

Similarly, anions like phosphate, can also be adsorbed against the positive charges developed on colloidal interfaces but usually anion exchange capacity of soils is lesser in magnitude.

Soil conditions characterized by physico-chemical properties like soil reaction, salt content and organic matter, activity of the soil micro-organisms, forms of nitrogen, phosphorus, potassium and other nutrients determine the nutrient availability and also the suitability of soils for successful crop production. It can be easily realised that the top or surface layer of the soil is the seat of maximum

activity and is most important in considering its fertility.

Potential productivity of soils varies considerably because of differences in their physical and chemical properties. However, a detailed examination of these properties and their correct evaluation would enable one to identify the constraints and to suggest the ways and means by which the inherently low productive soil could be made more productive. In actual practice, the physical and chemical analyses of soils indicate the conditions such as mechanical impedance, low water and nutrient retentivity, excessive and low permeability, acidity, alkalinity and lack of nutrients limiting crop production. Taking advantage of soil management practices such as deep tillage, compaction, addition of organic matter and fertilizers, soil productivity can be improved. In case of problem soils having excessive acidity or alkalinity, amendments like lime, gypsum, pyrites, etc. could be used for reclamation. How much room there remains for improvement is evidenced by the vivid example of the vast gap that exists between the potential yield obtained under well managed conditions and the national average yield of various crops.

1. Activity Unit

SOIL SAMPLING

1.1 Instructional objectives:

The pupil should be able to :

- explain the importance of correct sampling;
- identify the tools required for soil sampling;
- identify and demarcate the individual sampling unit;
- take soil samples;
- make composite soil samples;
- despatch soil samples to soil testing laboratories.

1.2 Relevant information :

1.2.1 *Soil sampling, Why?*

As only a very small fraction of the huge soil mass in the field is actually used for testing or analysis, it is essential that a truly representative soil sample is taken.

Soil sampling is done in order to find out the quantity of essential nutrients available to plants and other relevant physical and chemical characteristics which influence plant growth such as water retention, acidity, salinity, alkalinity, etc. It is also required for the determination of various physical and chemical properties of the soil.

1.2.2 *Soil sampling, When?*

It should be done when there is no crop in the field i.e., before raising the next crop and also prior to application of any manure or fertilizer. Rainy season should be avoided as far as possible for soil sampling work.

1.2.3 *Soil sampling, Where?*

Ten to fifteen samples should be drawn from an apparently homogenous plot. However, where the areas within a field look differently in appearance, crop growth, topography, drainage,

soil type, cropping pattern, or are known to have been fertilized or manured differently, divide the field into parts and sample each portion (constituting a sampling unit) separately. There is no rigidity about the size of the sampling unit.

1.2.4 Soil sampling: To what depth?

As root penetration is important for crop growth, soil is sampled for cereal crops to a depth of 0-15 cm (plough layer). For deep rooted crops like sugarcane, cotton and horticultural crops, soil samples should be collected from deeper zones as well (15-30 cm and if necessary up to 60 cm).

In case of saline-alkali or salt affected soils, salt crusts (visible or suspected) on the soil surface should be sampled separately and the depth of sampling recorded.

1.2.5 What is a composite sample?

The 10 to 15 soil samples collected from a homogenous sampling unit are pooled and intimately mixed and a smaller sample is drawn which should represent the entire sampling unit in its physical and chemical properties.

1.2.6 Requirements of a composite sample

- The volume and depth of each core or sample should be the same.
- The cores should be taken randomly.
- The number of cores should be enough to make the bulk of the soil and represent the field (sampling unit).
- The quantity of the sample should be adequate and sample should be homogenous for the objective of the analysis.

1.3 Precautions :

- Do not draw any sample from the extreme corners of the field, areas recently manured or fertilized, old bunds, marshy spots, manure piles and non-representative areas.
- Avoid sampling from furrows.
- Do not take less than 0.5 kg of a composite sample.
- Keep the sample in a bag and tag it properly. See that each sample tag carries the name of the farmer, number of field or identity of the field, depth of the sample, date preceeding and succeeding crops and signature with name of the sampler. Use ball point pen or copying pencil for writing on the tag.

- Avoid use of fertilizer bags for handling of soil samples.
- Follow proper procedure for sampling in saline and alkaline soils as it is different from the procedure described here for normal-soil conditions.

1.4 Materials required :

- i. Soil auger/soil tube/spade/pick-axe/*khurpi*
- ii. Bucket or tray
- iii. Paper tags (labels)
- iv. Information sheet
- v. Cloth bags (alternatively polythene bags)
- i. Ball point pen or copying pencil

1.5 Procedure :

Take a composite sample from each field as under :

- Remove the litter from the surface without much disturbing the soil (Fig.1.5.1).

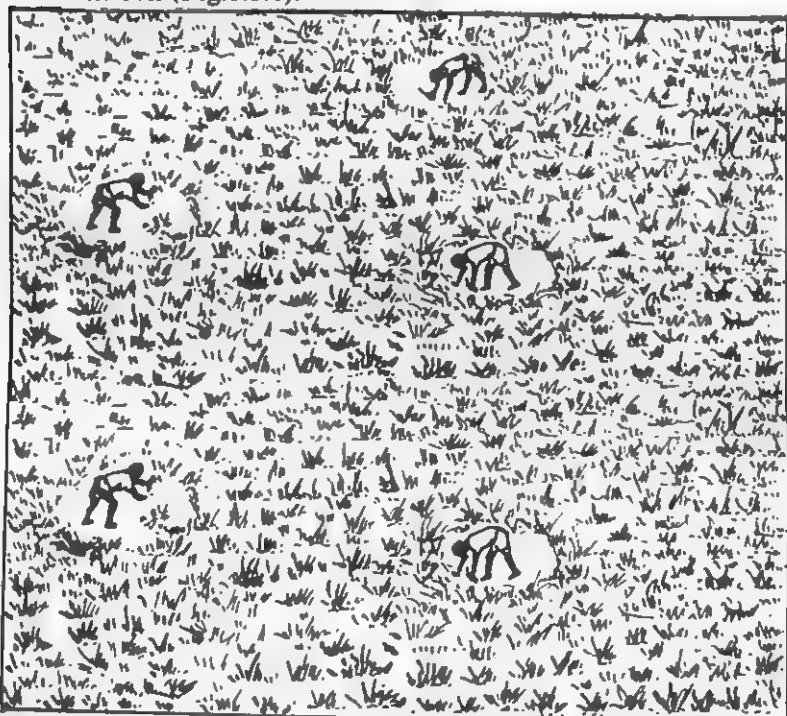


Fig. 1.5.1 REMOVING OF LITTER FROM FEW SELECTED SPOTS FOR SAMPLING

— Take soil samples from 10-15 random spots in a zigzag pattern in the field (Fig. 1.5.2) using a soil auger or by giving a

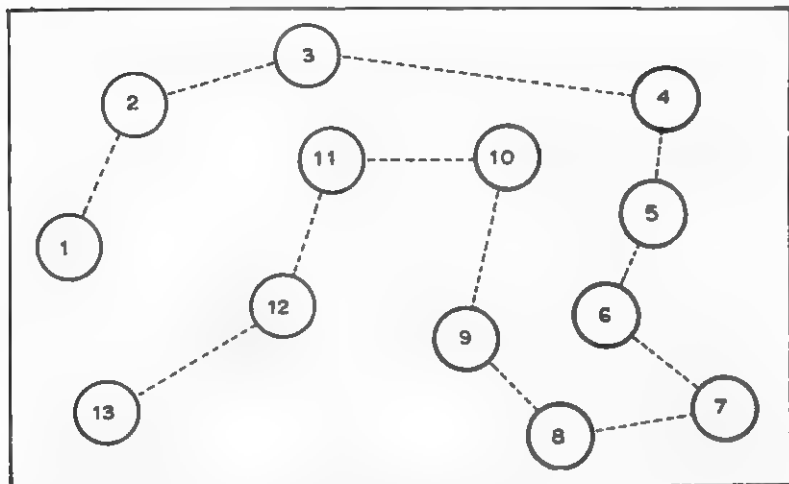


Fig. 1.5.2 SPOTS FOR SAMPLING IN A PLOT

V-shaped cut up to depth of 15 cm with spade or pick-axe or *khurpi* at each spot and take 1.5 - 2.0 cm thick uniform slice of soil and collect them in a clean and dry container or bucket (Fig. 1.5.3).

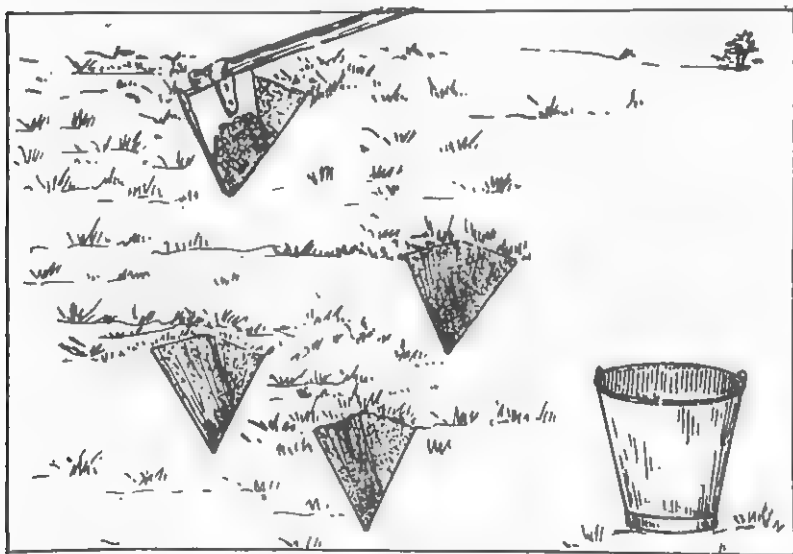


Fig. 1.5.3 TAKING OF UNIFORM SLICE OF SOIL FROM EACH SPOT

- Mix thoroughly the soil collected from different spots of the field and take atleast 0.5 kg composite sample as follows:
- Spread the soil in a disc-like shape and divide the soil collected into four parts (quartering) and discard one set of opposite quarters (Fig.1.5.4).

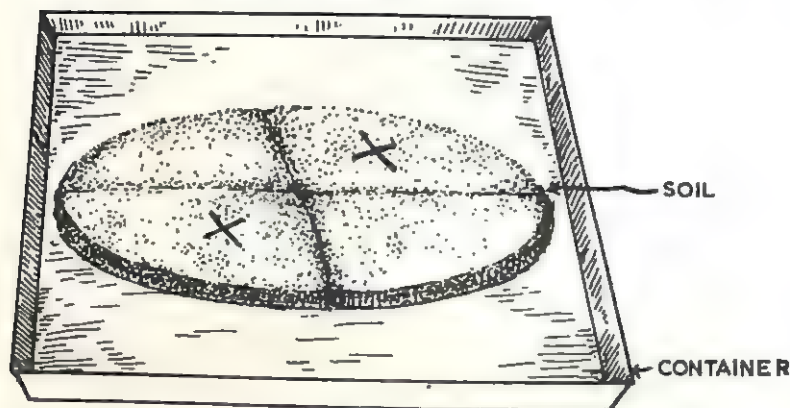


Fig. 1.5.4 DIVIDING OF COLLECTED SOIL MASS INTO FOUR PARTS AND DISCARDING ANY TWO

- Mix well the soil of remaining two quarters and repeat this till the sample size is reduced to 0.5 to 0.75 kg (by taking only two parts) and put in a clean cloth bag free from any contamination of fertilizer, salts, etc. Polythene bags can also be used.
- Air dry the sample under the shade. Do not dry the soil directly under sunlight or by artificial heating.
- Prepare two labels (Fig. 1.5.5) one to be put inside the bag and the other to be tied on the neck of the bag.

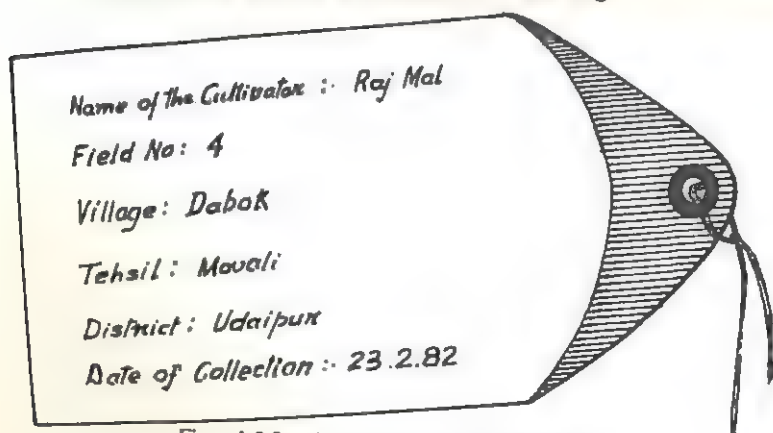


Fig. 1.5.5 A LABELLED PAPER TAG

- Collect the following information and fill in the information sheet:
 - Name of the farmer
 - Identity or number of the field
 - Date of sampling
 - Address of the farmer
 - Name of the sampler and signature
 - Local name of soil, if any
 - Colour of soil (dry and moist)
 - Type of land (unirrigated, irrigated, water-logged)
 - Source of irrigation (canal, well, tank)
 - Natural drainage or water table
 - Topography (level, slopy, undulated)
 - Crop rotation followed
 - Previous crop
 - Next crop to be taken
 - Details of manures or soil amendments applied earlier
 - Name of the important trees of the area
 - Any other remarks like salt incrustations, depressions, shade, saline/alkali symptoms, etc.
- Pack the soil sample bags along with information sheet in a clean and dry gunny bag and write down the name, address of the laboratory where it is to be analysed.

1.6 Observations :

The pupils should observe the following :

- Whether the quantity of each soil sample is adequate?
- Whether the paper tag carries required information?
- Whether the soil sample bag is properly tagged?
- Whether the information sheet has been correctly prepared?
- Whether the soil sample bags are properly packed for transportation to the laboratory?

1.7 Expected behavioural outcomes :

- The pupil will be able to:
- identify tools for soil sampling;
 - select suitable points/places from where soil samples should be collected;
 - take slice/core of soil;
 - prepare the composite sample;
 - label and tie the cloth/polythene bags;
 - prepare the information sheet.

Grade

The teacher should evaluate the pupil for the above abilities.

1.8 Questions :

- i. How packing of soil sample bags in an empty fertilizer bag can affect the composition of soil?
- ii. Why soil samples are not taken from furrows, manure piles, corners, etc.?
- iii. Why sampling should not be done from only one location in the field sampling unit?
- iv. Why soil samples should not be collected while raining?
- v. Why drying of the soil samples directly under sun or by heating is to be avoided?
- vi. Which of the following you will use for writing on the labels?
(Put a tick (✓) mark).
 - (a) Pencil
 - (b) Fountain pen
 - (c) Ball-point pen
- vii. What name will you give to a 0-15 cm depth of soil?
- viii. What do you mean by a composite soil sample?
- ix. Why cleaning of soil surface before taking soil sample is essential?
- x. Why special sampling procedure should be adopted in the case of salt affected soils?

2. Activity Unit

PREPARATION OF SOIL SAMPLE IN THE LABORATORY AND DETERMINATION OF MOISTURE CONTENT IN THE SAMPLE

2a. Sub Unit : Preparation of Soil Sample

2a. 1 Instructional objectives:

The pupil should be able to :

- receive and properly record the soil samples;
- process the soil samples for analyses.

2a. 2 Relevant information :

Receiving, recording and preparation of individual samples are very important as errors will get magnified to the level that further analysis may be of no value.

2a. 3 Precautions :

- Register the samples carefully
- Use wooden mallet/wooden pestle and not any metal mallet/pestle for grinding
- Do not crush any gravel/stones or concretions.
- Weigh the material that does not pass through 2 mm sieve and find out the percentage to the total amount.
- See that no rootlets or fresh, partly or decomposed organic matter enter the sample while preparing the same. Keep the prepared sample in a dry place and protect it from rats, white ants, etc.

2a. 4 Materials required :

- i. Wooden mallet/wooden pestle

- ii. Good paper carton/bags for storing
- iii. Storage cabinet, if available
- iv. Barranger or pan type/physical balance
- v. Sieve 2 mm size

2a. 5 Procedure :

- Check the bags for their intactness.
- Check the information provided on tag and enclosed sheet.
- Enter the information in the register.
- Assign a serial number to each sample as per the register.
- Dry the soil sample if needed in the air under shade.
- Grind the sample (to break the aggregates) with a wooden mallet or wooden pestle.
- Sieve the sample by using 2 mm sieve.
- Collect the sample which passes through the sieve for analysis in a numbered bottle or bag.

2a. 6 Observations :

The pupil should observe the following :

- Whether the soil sample contains too much of coarse particles?
- Whether the soil sample contains too much of organic residues?

2a. 7 Calculations :

The pupil should calculate the proportion of coarse particles in the soil sample.

Total amount of soil taken for preparation = X g

Amount of coarse particles (> 2 mm) = Y g

Percentage of coarse particles = $Y/X \times 100$

2a. 8 Expected behavioural outcomes :

The pupil will be able to :

- receive and register soil samples;
- prepare samples;
- preserve the samples properly.

Grade

The teacher should evaluate the pupil for the above abilities.

2a. 9 Questions :

- i. Why the samples be registered?
- ii. Why should they be kept in a dry place?
- iii. Why should a wooden mallet/wooden pestle be used?
- iv. Why the samples should be passed through 2 mm sieve?

- v. Why should the percentage of coarse fractions (> 2 mm) be calculated?

2b. Sub Unit : Determination of Moisture Content in Soil Sample

2b. 1 Instructional objective :

The pupil should be able to :

- estimate the moisture in air-dry sample.

2b. 2 Relevant information :

2b. 2. 1 Importance of soil moisture determination

Even after air drying, the soil retains variable quantity of moisture. This determination provides a means for comparing the analytical values of samples with different moisture contents on moisture free basis.

2b. 2. 2 How soil moisture content is expressed?

Soil moisture is normally expressed as percentage on weight basis (g of water per 100 g of oven-dry soil); it can however, be expressed on volume basis, if required. The relationships are given below:

Moisture on dry weight basis $\Theta W = W_m / W_s \times 100$

Moisture on volume basis $\Theta V = V_m / V_s \times 100$

Where: W_m = Weight of moisture in g

W_s = Weight of oven dry soil in g

V_m = Volume of moisture in cubic cm

V_s = Volume of soil in cubic cm

As it will be seen in Activity 3, moisture content on dry weight can be converted to volume basis by multiplying it with bulk density (Db) of soil;

$$\Theta V = \Theta W \times Db$$

2b. 3 Precautions :

- Dry in oven the air-dry soil sample to a constant weight (no further loss of moisture) by heating so that it loses moisture slowly.
- Check the automatic temperature control of the oven.

- Close the lid of the moisture box immediately after drying. Cool it in the desiccator for the minimum period necessary and the weighing should be done as quickly as possible.

2b. 4 Materials required :

- Aluminium moisture box with lid
- Physical balance with weight box
- Desiccator with desiccant viz., anhydrous or fused calcium chloride
- Oven with thermometer 0—110°C

2b.5 Procedure :

Gravimetric method

- Take weight of empty moisture box with lid.
- Place about 50 to 70 g of soil and weigh (up to 2nd place).
- Dry the soil for 24 hours at 105°C. This can be done in 2 or 3 stages of 8 to 12 hours each.
- Cover the box with lid.
- Cool it in the desiccator.
- Weigh it.
- Repeat the above procedure till the consecutive weights are constant.

2b. 6 Observations :

The pupil should record the weights against the following items :

Weight of empty box with lid = X g

Weight of box + lid + moist or airdry soil = Y g

Weight of box + lid + oven-dry soil = Z g

2b. 7 Calculations :

The pupil should calculate the percentage moisture by weight and volume basis.

— Weight of water lost during drying = $(Y - Z)$ g

— Weight of oven-dry soil = $(Z - X)$ g

— Percentage moisture by dry weight = $(Y - Z) / (Z - X) \times 100$

— Percentage moisture by volume = $(Y - Z) / (Z - X) \times 100 \times Db$
(Db = Bulk density)

2b. 8 Expected behavioural outcomes :

The pupil will be able to :

- weigh the samples correctly up to second decimal place;
 - calculate the moisture content on dry weight basis;
 - calculate the moisture content on volume basis.
- The teacher should evaluate the pupil for the above abilities.

Grade

2b. 9 Questions :

- i. Why the soil should be dried to constant weight?
- ii. Why the drying of soil sample is to be done up to 105°C only?
- iii. Why is soil moisture expressed on dry weight basis?
- iv. A soil sample has 20 percent moisture on dry weight basis. Its bulk density is 1.5 g/cc . What is the moisture content on volume basis? If the sample is collected from 30-cm soil depth, what is the depth of soil moisture?
- v. Soil sample was collected with a core sampler of volume 500 cc. The weight of moist soil was 880 g and the weight of oven dry soil was 800 g. Calculate (a) moisture content by weight (b) the density of moist soil, and (c) the moisture content by volume.
- vi. A soil sample brought from a field weighing 48 g lost 8 g in weight on oven-drying. Find out the moisture content on volume basis if 100 cc of oven dry soil weigh 140 g.

3. Activity Unit

DETERMINATION OF BULK DENSITY OF SOIL

3.1 Instructional objectives :

The pupil should be able to :

- identify the materials required for the determination of apparent or bulk density;
- take representative core sample from the field;
- calculate the volume of the core tube;
- determine the moisture present in the core sample;
- calculate bulk density of the soil;
- relate change in bulk density to soil management practices such as tillage and addition of organic matter of the soil.

3.2 Relevant information :

3.2.1 What is bulk density ?

The bulk density (also known as apparent density) is defined as the mass per unit volume which includes volume (space) occupied by solids as well as pore spaces. This is expressed by the relationship:

$$\text{Bulk density (Db)} = \text{Mass (W)} / \text{Volume (V)}$$

The bulk density is usually expressed in grams per cubic centimetre (g/cc).

3.2.2 What are the factors affecting bulk density of soil?

The bulk density is influenced by a variety of factors such as particle size and distribution, pore space, organic matter content, depth of soil and mechanical manipulation (tillage, ploughing, compaction, etc.). Increase in clay and organic matter content decreases the bulk density. The bulk density of the soil generally increases with depth which is due to low organic matter content and compaction resulting from over-burden pressure.

3.2.3 What is the significance of bulk density of soil?

Bulk density is used in estimating porosity, void ratio, weight of the furrow slice (0-15 cm), and converting soil moisture from weight to volume basis.

3.3 Precautions :

- Select a representative site of the field for sampling.
- Do not take soil core sample in very wet or dry soil conditions.
- Place a block of wood over the core tube while hammering.
- Use metal core tube of 5 cm diameter or more to reduce the error arising due to compression of soil during sampling.
- Weigh immediately after taking the core sample.

3.4 Materials required :

- i. Balance (Physical)
- ii. Weight box
- iii. Moisture box
- iv. Core tube with hammer
- v. Vernier calliper
- vi. Oven
- vii. Knife
- viii. Desiccator

3.5 Procedure :

- Measure accurately the length and diameter of the core tube (Fig. 3.5.1) with the help of vernier calliper.

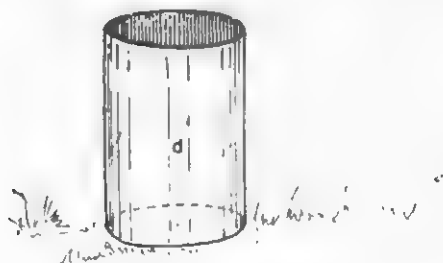


Fig. 3.5.1 A CORE TUBE

- Select a representative area in the field, clean the surface litter, if any and press the core tube vertically into the soil by hand; place the wooden block and press further by steady hammering (Fig. 3.5.2) till the core sampler is driven down to

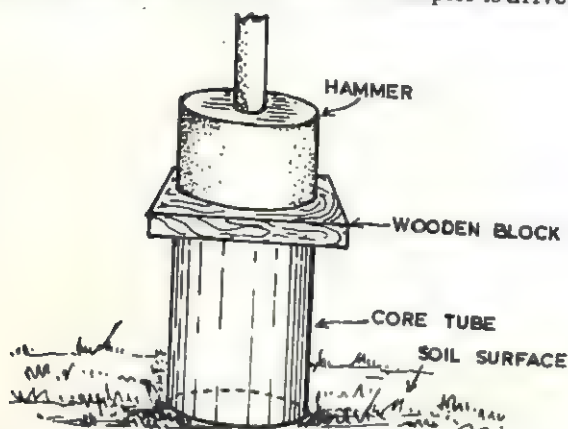


Fig. 3.5.2 PRESSING OF CORE TUBE IN THE FIELD

- the surface of the soil, filling it completely.
- Remove the soil from outside the core tube to facilitate easy withdrawal of the tube alongwith the core from the field.
- Put your palm at the bottom of the core tube while withdrawing it from the field in order to check falling of soil from the tube (Fig. 3.5.3).



Fig. 3.5.3 REMOVING OF CORE TUBE ALONG WITH THE SAMPLE FROM THE FIELD

- Remove the excess soil sticking to the core tube with the help of a knife.
- Remove the soil from the core tube and weigh it.
- Take a homogenous sample of core soil, say 20-30 g in a weighed moisture box.
- Weigh the moisture box and place it in an oven for drying at 105°C to constant weight.
(Normally this may take 24 hours).
- Take out the moisture box and place it in a desiccator.
- Weigh the moisture box and determine the per cent moisture content in the soil.
- Calculate the moisture content in the entire core.
- Subtract the moisture content from the original weight of the core and get the weight of dry core.

3.6 Observations :

The pupil should take the following measurements and weight of the soil.

- i. Length of the core tube = $h(\text{cm})$
- ii. Diameter of the core tube = $D(\text{cm})$
- iii. Weight of the dry core = $W(\text{g})$

3.7 Calculations :

The pupil should calculate the bulk density (D_b) as per formula given below :

$$\text{Volume of the core tube} = \pi (D/2)^2 h \text{ in cc}$$

$$\text{Bulk density } (D_b) = W / \pi (D/2)^2 h = \text{g/cc}$$

3.8 Expected behavioural outcomes :

The pupil will be able to :

- measure the diameter and length of core tube with the help of vernier calliper;
- select the site for core sampling;
- insert and remove core tube;
- weigh the sample;

Grade

— relate bulk density data to texture, organic matter content and mechanical manipulation in samples collected from different site situations;



— calculate the bulk density.

The teacher should evaluate the pupil for the above abilities.

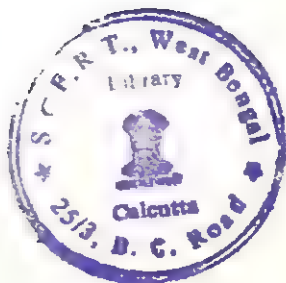
3.9 Questions :

- i. Why is the determination of bulk density important?
- ii. How is bulk density expected to vary with changes in sand, clay, and organic matter content and also with soil aggregation?
- iii. Name the factors which affect bulk density of a soil.
- iv. Why should bulk density be determined when the soil is not too wet or too dry?
- v. Calculate the moisture percentage on volume basis (Θ_V) when moisture percentage on weight basis (Θ_W) is 5% and bulk density (D_b) is 1.50 g/cc.
- vi. Why the bulk density is to be determined with undisturbed core sample of soil?

S.C.E.R.T., West Bengal

Date 14-1-87

Acc. No. 3724



4. Activity Unit

DETERMINATION OF PARTICLE/REAL DENSITY OF SOIL

4.1 Instructional objectives :

The pupil should be able to :

- explain the principles involved in the determination of particle or real density;
- determine particle density of soil;
- differentiate between bulk (apparent) density and particle (real) density of soil;
- recall the usual range of particle density in soils and reason for low and high values.

4.2 Relevant information :

4.2.1 What is particle density?

Particle density refers to the actual density of soil solids. It is defined as the mass per unit volume of soil solids only. This is expressed by this relationship:

Particle density (D_p) = Mass (W) / Volume of solids (V_s)

The particle density is usually expressed in g/cc. Since the volume is exclusive of pore spaces, the value of particle density is higher than that of bulk density.

4.2.2 What are the factors affecting particle density?

The particle density of most soils ranges between the narrow limits of 2.50 to 2.75 g/cc with an average value around 2.60 g/cc. This is because most mineral particles are quartz, feldspars and other silicates whose densities also vary within the same limits. However, particle density of the soil may differ from the usual range due to presence of large amounts of organic matter and heavy minerals such as magnetite, garnet, epidote, zircon, etc. Unlike bulk density,

particle density of a soil is not altered by mechanical manipulation.

4.2.3 What is the significance of particle density of soil?

It is used in the estimation of porosity, void ratio and settling velocity of soil particles using Stoke's law (Activity Unit 6).

4.2.4 What is the principle of determination ?

Particle density requires the measurement of two variables i.e. mass and volume of soil solids. Mass is determined by weighing oven dry soil. Volume of the soil is determined by the volume of water displaced when soil is immersed therein. The accuracy of method depends upon how closely the volume of displaced water approaches that of the true volume of soil solids.

4.3 Precautions :

- Take a representative prepared soil sample and remove organic debris.
- Use boiled and cooled distilled water/rain water.
- Clean and dry the pycnometer before using it.
- Ensure the removal of all entrapped air (bubbles) from the soil submerged in water.

4.4 Materials required :

- i. Pycnometer (Specific gravity bottle)
- ii. Analytical balance and weight box
- iii. Pipette
- iv. Blotter/ordinary filter paper/piece of clean cloth.

4.5 Procedure :

- Weigh a clean dry pycnometer (Fig. 4.5.1) with stopper on.



Fig. 4.5.1 A PYCNOMETER

- Transfer 10 g of oven-dry soil into the pycnometer (Fig. 4.5.2).



Fig. 4.5.2 A PYCNOMETER WITH SOIL

- Fill the pycnometer to about half its volume with water using a pipette, washing into the flask any soil particles sticking inside the neck. Allow enough time for the water to completely soak into the soil.
- Remove the entrapped air by filling the bottle with distilled water to the brim (Fig. 4.5.3).



Fig. 4.5.3 A PYCNOMETER WITH SOIL AND WATER FILLED UPTO THE TOP

- Insert the stopper and wipe out the outer surface of the pycnometer with a blotter to remove water adhering to it and weigh the pycnometer; record this weight.
- Empty the pycnometer, fill it again with distilled water (Fig. 4.5.4), replace the stopper, wipe out water adhering on the outside with a blotter, weigh the pycnometer and record this weight.



Fig. 4.5.4 A PYCNOMETER WITH WATER

4.6 Observations :

The pupil should take the following weighings :

Weight of oven dry soil = W (10 g)

Weight of pycnometer with soil and water = W_1 g

Weight of pycnometer filled with water alone = W_2 g

4.7 Calculations :

The pupil should calculate the particle density as per formula given below :

Particle Density (D_p) = $\frac{\text{Wt. of oven dry soil}}{\text{Volume of oven dry soil}}$

Weight of oven dry soil = W (10 g)

Volume of oven dry soil = Volume of displaced water

= $(W_2 + 10g - W_1) \times \text{Density of water}$

$D_p = (10 \text{ g}) / (W_2 + 10g - W_1) \times \text{Density of water (g/cc)}$

4.8 Expected behavioural outcomes :

The pupil will be able to :

- weigh accurately;
- fill the pycnometer correctly;
- remove the entrapped air bubbles.

Grade

The teacher should evaluate the pupil for the above abilities.

4.9 Questions :

- i. Why is the value of particle density always higher than that of bulk density of a soil?
- ii. What are the conditions under which particle density

deviates from the common range of normal soils?

- iii. Why is it essential to remove the entrapped air?
- iv. Why do the particle density values vary within the narrow limits of 2.5 to 2.75 g/cc?
- v. Why is particle density not affected by mechanical manipulation of the soil?
- vi. What is the effect of temperature on the determination of the real density of particles by the pycnometer method?

5. Activity Unit

COMPUTATION OF PORE SPACE IN SOIL

5.1 Instructional objectives :

The pupil should be able to :

- compute pore space from bulk density and particle density data of a soil;
- explain the reasons for variation in pore space among different soils;
- relate variation in porosity of a soil to its mechanical manipulation and organic manuring.

5.2 Relevant information :

5.2.1 *What is pore space?*

Pore space refers to the portion of soil volume not occupied by the solid particles. It is filled with air, water or both. The amount of pore space in a soil is expressed as a percentage of the total volume.

5.2.2 *Significance of pore space for plant growth*

Several important soil and plant processes such as retention and movement of water in soil, gas exchange between the soil and the atmosphere, solute movement and proliferation and penetration of roots depend on the amount and size distribution of pores.

In general, two types of pores—micro (capillary pores) and macro pores (non-capillary pores) are recognised. Generally, the micro pores hold water while air is held in macropores. In order to maintain a favourable air-water relationship for plant growth, there should not only be sufficient total pore space but also a proper balance between the two kinds of pores. In an ideal soil, total pore space should be more or less equally distributed between two types of pores.

5.2.3 *Factors affecting porosity*

The total porosity of a medium (loamy) textured soil varies in

the neighbourhood of 50 per cent. Sandy soils usually have lower porosity while clay and organic matter rich soils have higher values. Subsoils which are generally compacted have less pore space than the surface soils. In a coarse textured (sandy) soil, the proportion of macro pores is greater whereas in a fine textured (clay rich) soil the proportion of micro pores is greater. Compaction of a coarse textured soil reduces the total porosity but increases the proportion of micro pores. Since total porosity is estimated from bulk density of a soil, factors such as texture, structure, organic matter content and cultivation, influencing the latter, also affect the total porosity.

5.3 Precautions :

Refer to sub head 3.3 and 4.3

5.4 Materials required :

Same as sub head 3.4 and 4.4

5.5 Procedure :

Refer to sub head 3.5 and 4.5

5.6 Observations :

The pupil should use the values obtained in Activity units 3 and 4 for bulk density and particle density.

— Particle density of soil (g/cc) = D_p

— Bulk density of the soil (g/cc) = D_b

5.7 Calculations :

The pupil should calculate the per cent pore space by the following expression :

$$\text{Per cent pore space} = (1 - D_b / D_p) \times 100$$

5.8 Expected behavioural outcomes :

The pupil will be able to :

- compute the porosity from bulk density and particle density data;
- explain the changes in porosity due to soil management;

Grade

— appreciate the changes in water retention due to compaction of a coarse textured soil.



The teacher should evaluate the pupil for the above abilities.

5.9 Questions :

- i. How is porosity determined?
- ii. What should be the distribution of macro and micro pores in a soil to maintain optimum air water relationship for plant growth?
- iii. Why does a coarse textured soil retain less water but also allow the water to move rapidly?
- iv. Which soil has more of pore space—fine textured or coarse textured?
- v. Does pore space affect the particle density?

6. Activity Unit

MECHANICAL ANALYSIS OF SOIL BY HYDROMETER METHOD

6.1 Instructional objectives :

The pupil should be able to :

- explain the principle involved in using the hydrometer in relation to settling velocity of soil particles in water;
- find out percentages of different mechanical separates of the soil;
- find out the textural name of the soil from the triangular diagram.

6.2 Relevant information :

6.2.1 *Texture*

It indicates fineness or coarseness of the soil depending upon the relative proportion of the solid particles (sand, silt, clay) of varying sizes.

6.2.2 *Soil separates :*

The soil mineral particles which result from weathering of rocks vary greatly in size and shape. These are classified into gravel, sand, silt and clay on the basis of their size. Clay particles are so small that they are not ordinarily visible. Sand grains feel gritty and are easily seen by the naked eye. Silt is intermediate in size between clay and sand. Gravels range from pebbles to particles of 0.20 cm and above. The various size groups (primary particles) are termed as soil separates. The general characteristics of the soil separates are given in Table 6.2.1.

Table 6.2.1 Characteristics of soil separates

Soil separates	Diameter * in mm	Feel of soil separates	Composition
Coarse sand	2.00—0.20	Very gritty	Primary minerals
Fine sand	0.20—0.02	Gritty	—do—
Silt	0.02—0.002	Flour like	Primary and secondary minerals
Clay	< 0.002	Very smooth	Mostly secondary minerals

* International system proposed by Atterberg.

Most soils are mixtures of the various sized particles except that many contain no gravel and some very little sand or clay. If a soil has equitable distribution of coarser and finer particles, it is known as a loam. It may be called a sandy or clay loam, depending on soil particles that predominate. If the soil consists mostly of particles of one size group it may be called clay, silt or sand, depending on the dominant particle. Textural class of a soil can be determined with the help of the Triangle Diagram (Fig. 6.2.1), if percentages of any two of the three primary particles (sand, silt and clay) are available.

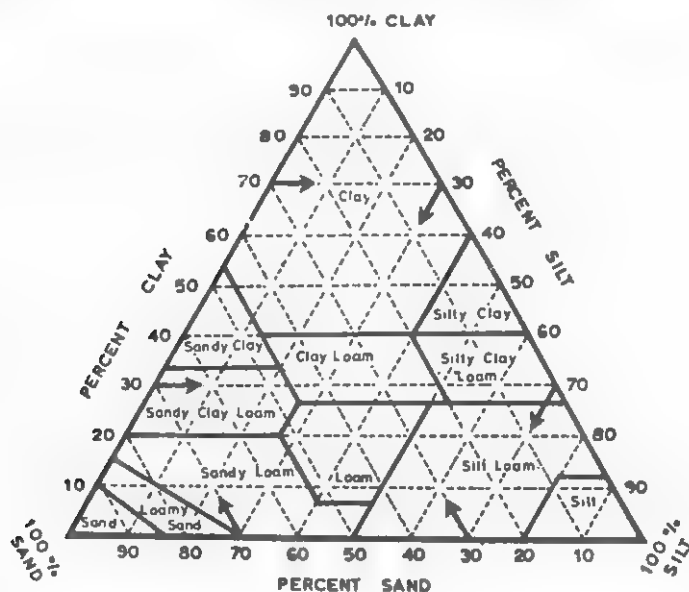


Fig. 6.2.1 TRIANGLE DIAGRAM TO DETERMINE TEXTURAL CLASS OF SOIL

According to United States Department of Agriculture (USDA) system, proportion of primary particles in various textural classes are given in Table 6.2.2.

Table 6.2.2. Percentage of sand, silt and clay in principal textural classes (USDA, 1960)

<i>Textural name</i>	<i>Ranges (per cent)</i>		
	<i>Sand</i>	<i>Silt</i>	<i>Clay</i>
Sand	85—100	0—15	0—10
Loamy sand	70—90	0—30	0—15
Sandy loam	43—80	0—50	0—20
Loam	23—52	28—50	7—27
Silt loam	0—50	50—88	0—27
Silt	0—20	80—100	0—12
Sandy clay loam	45—80	0—28	20—35
Clay loam	20—45	15—53	27—40
Silty clay loam	0—20	40—73	27—40
Sandy clay	45—65	0—20	35—45
Silty clay	0—20	40—60	40—60
Clay	0—45	6—40	40—100

The 12 textural classes may be regrouped, as under, based on the relative ease of draught required to pull tillage equipment especially the plough. Please note that these terms are not related to particle or bulk density.

Heavy soils	— sandy clay, silty clay, clay.
Medium soils	— sandy loam, loam, silty loam, silt, silty clay loam, sandy clay loam, clay loam.
Light soils	— sand, loamy sand.

6.2.3 Mechanical analysis of soil

The determination of relative distribution of the size groups of ultimate particles is called mechanical analysis. Following methods are employed for the determination.

- a) International pipette method
- b) Hydrometer method

The international pipette method is designed for more accurate determination of the proportion of soil separates but the process is time-consuming. Hence, hydrometer method which is considerably faster and fairly accurate enough for most purposes is adopted.

6.2.4 Principles behind hydrometer method

The settling velocity of a solid particle in a liquid at a particular temperature due to the action of gravity directly depends upon (i) the size of the particles, (ii) the difference between the densities of the solid and the liquid medium and also is inversely related to the viscosity of the liquid.

6.2.5 Stoke's law

In the year 1851, Stoke gave a mathematical relationship of the velocity of a falling particle in a liquid medium as given below:

$$V = \frac{2}{9} \frac{g r^2 (d_1 - d_2)}{\eta}$$

Where : V = Velocity of fall (settling velocity) cm/sec

r = radius of particle, cm

d_1 = density of particles, g/cc

d_2 = density of liquid, g/cc

η = viscosity of the liquid, poise

g = acceleration due to gravity, m/sec²

The density of the suspension at a given depth decreases as initially homogeneous dispersed particles settle down. The rate of decrease in density at any given depth is related to the settling velocities of the particles which obey the Stoke's law. Hydrometers based on the above principles specially designed for soils such as Bouyoucos hydrometers are used in this analysis.

6.3 Precautions :

- Ensure that the soil suspension at the beginning of experiment is homogeneous.
- Immerse the hydrometer in the suspension very carefully and gently.
- Avoid temperature fluctuations.
- Be sure of a uniform dispersion when the organic matter is more and take a larger quantity of sample.

6.4 Materials required :

- i. Cylinder (100 ml) with rubber stopper
- ii. Thermometer
- iii. Sodium hexametaphosphate (5 per cent solution)
— Calgone.
- iv. Hydrogen peroxide (6 per cent or 20 volumes)

- v. Wash bottle
- vi. Beaker (600 ml) with cover
- vii. Hot plate or water bath
- viii. Bouyoucos hydrometer
- ix. Watch glass
- x. Chemical balance
- xi. Soil sample, 2 mm sieved (80 g)
- xii. Stirring rod
- xiii. Electrical stirrer with dispersing cup
- xiv. Amyl alcohol
- xv. Stop watch or wrist watch

6.5 Procedure :

- Take 10 ml of sodium hexametaphosphate solution in one litre cylinder. Fill the cylinder with distilled water to make exactly one litre and shake it well.
- Lower the soil hydrometer into the solution and take the scale reading. Record this reading as RB, the calibration correction.
- Weigh in duplicate, 40 g of 2 mm sieved soil samples.
- Determine the moisture content of one of the sample as given in Activity Unit 2.
- Transfer the other sample to 600 ml beaker and add 200 ml of distilled water and 5 ml of hydrogen peroxide (H_2O_2). Cover the beaker with watch glass and put it on the water bath for decomposition of organic matter till frothing is over. Cool the beaker. Repeat the process until frothing stops or the suspension ceases to become lighter in colour.
- Once again put the beaker on water bath for two hours to remove H_2O_2 . [Note: In soils with low organic matter content (less than 1%) H_2O_2 treatment can be dispensed with].
- Transfer the sample to dispersing cup make up to 250 ml with water and add 10 ml of sodium hexametaphosphate solution and keep for 15 minutes.
- Stir the soil suspension in the cup with the help of an electrical stirrer for 10 minutes. The time may vary from 5 minutes for sandy soils to 30 minutes for heavy soils.
- Pour and wash the contents of the dispersing cup into a one litre cylinder.
- Fill the cylinder with distilled water to one litre mark. Place a rubber stopper on the cylinder and shake the cylinder by hand

- for one minute keeping it in horizontal position.
- Place the cylinder on the table and note the time immediately with stop watch or wrist watch.
 - Insert the hydrometer into the cylinder (Fig. 6.5.1.) after 3 minutes 50 seconds carefully and take the reading at exactly four minutes, when the particles larger than 0.02 mm in diameter have settled out. (Note : If the surface of the suspension is frothy, add one drop of amyl alcohol).

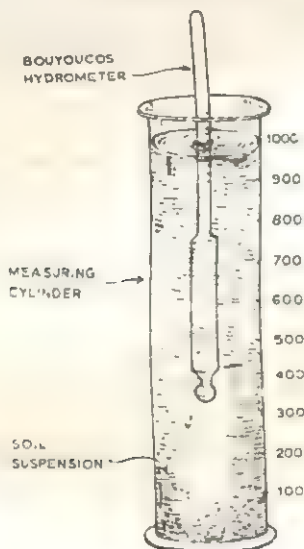


Fig. 6.5.1 A HYDROMETER IN SOIL SUSPENSION

- Remove the hydrometer and wash it.
- Measure and record the temperature of the suspension.
- Keep the suspension undisturbed for 1 hr 59 minutes and 50 seconds and reinsert the hydrometer. Take the reading at the end of 2 hours from the time shaking was stopped. At this moment, particles larger than 0.002 mm i.e. sand and silt would have settled down.

6.6 Observations :

The hydrometer is calibrated at 67°F (20°C). In case of change in temperature, a correction must be applied. If the temperature of the suspension at the time of working is above 67°F, the correction is added, below 67°F the correction is subtracted. For each °F above or

below 67°, it should be multiplied by 0.2. The pupil should take the following readings and do the necessary calculations as per the formula given below :

Hydrometer reading at 4 minutes	= R_1
Hydrometer reading at 2 hours	= R_2
Oven dry weight of soil sample	= W
Temperature correction	= r
Calibration correction	= RB

6.7 Calculations :

The pupil should calculate the percentage of dispersed material remaining in the suspension at any time by the following formulae :

$$\% \text{ silt + clay} = A = \frac{R_1 - RB + r}{W} \times 100$$

$$\% \text{ clay} = B = \frac{R_2 - RB + r}{W} \times 100$$

$$\% \text{ silt} = \frac{(\text{clay + silt}) - (\text{clay})}{(A) - (B)}$$

$$\% \text{ sand} = 100 - (\% \text{ silt + clay}) = 100 - (A)$$

Determination of textural class

Use triangular diagram (Fig. 6.2.1.) for the determination of textural name of the soil by using sand, silt and clay percentages obtained by hydrometer method as given below :

Locate the percentage of sand in base line and move along the line parallel to silt line. Then locate per cent silt on the silt line and go along the line parallel to clay and then locate per cent clay on the clay line and move along the line parallel to sand; the point at intersection of all the three lines gives the texture of the sample.

Textural name of the soil = .—.—.—.—.—.—.—.

6.8 Expected behavioural outcomes :

The pupil will be able to :

- identify the materials;
- prepare the soil suspensions;
- handle the hydrometer;
- take the hydrometer readings;
- calculate the percentages of sand, silt and clay;
- use the triangle diagram for the determination of textural name of the soil

Grade

The teacher should evaluate the pupil for the above abilities.

6.9 Questions :

- i. What is meant by heavy soil? Why is it so called?
- ii. Find out the textural class of a soil which contains 20 per cent clay and 12 per cent silt and remaining sand.
- iii. What is the role of the following chemicals in mechanical analysis?
 - a) Hydrogen peroxide
 - b) Sodium hexametaphosphate.
- iv. Arrange the following soils in order of fineness: sandy loam, silty loam, loamy sand, clay loam, loam, silty clay loam, clay, sandy clay loam, silt.
- v. Indicate the size range of the following soil separates: clay, silt and sand.
- vi. How does the soil hydrometer differ from ordinary hydrometers?
- vii. What precautions should be taken during hydrometer estimation?
- ix. Why is temperature correction necessary?

7. Activity Unit

DETERMINATION OF SOIL TEXTURE BY FEEL METHOD

7.1 Instructional objective :

The pupil should be able to :

— find out the approximate texture of the soil in the field.

7.2 Relevant information :

Required information is given in the preceding activity unit.

7.3 Precaution :

— Test the soil at a number of spots from most representative areas of the field before coming to a conclusion about the texture of the soil.

7.4 Materials required :

- i. Soil sampler (any hand tool)
- ii. wash bottle
- iii. watch glass

7.5 Procedure :

- Take a pinch of soil sample, wet and rub between thumb and forefinger and note the feel at the fingers. Heavy soils exhibit stickiness when wet and are hard on drying. Silt when dry, feels like talcum powder or flour and exhibits slight stickiness. Sand feels gritty and its particles can be easily seen with the naked eye.
- Moisten a sample just enough to make an one cm ball. Hold the ball between the thumb and the forefinger. Press your thumb forward gradually, forming the soil into a ribbon (Fig. 7.5.1).



Fig. 7.5.1 FORMS A LONG RIBBON FROM A BALL OF MOISTENED SOIL

- If the ball turns into a ribbon easily and remains long and flexible upon pressing, the sample is probably clay or silty clay and is considered heavy or fine textured soil. Such soils are sticky and plastic (retaining the shape given to it).
- If ribbon forms but breaks into 2 to 2.5 cm long pieces (Fig. 7.5.2), the soil is moderately fine textured that is either clay loam or silty clay loam and is moderately sticky and plastic.



Fig. 7.5.2 FORMS A RIBBON BUT BREAKS INTO PIECES

- When a long ribbon is not formed and the ribbon breaks into pieces of less than 2 cm (Fig. 7.5.3), it is probably silt loam, sandy loam or loam. The soil is medium textured or moderately coarse textured.



Fig. 7.5.3 RIBBON DOES NOT FORM AND THE SOIL FEELS VERY GRITTY

- If the soil feels smooth and talc like, with no grittiness and silt predominates, the soil is medium textured. If it feels slightly gritty, yet fairly smooth and talc like, it is probably a loam or silt loam and can be included in medium textured group.
- If the sample feels extremely gritty without any smoothness, it is sandy or moderately coarse textured.
- If the sample almost consists of gritty material and leaves no stain on the hand (Fig. 7.5.4), it is a coarse textured soil or sandy soil.



Fig. 7.5.4 SAMPLE CONSIST OF GRITTY MATERIAL AND LEAVES NO STAIN ON THE HAND

7.6 Observations :

The pupil should go round the field and observe the following physical characteristics:

- Colour
- Approximate depth of the soil
- Sloppiness
- Feel when dry
- Feel when moist (grittiness talc like smoothness)
- Formation of ribbon and its stability
- Texture

7.7 Expected behavioural outcomes :

The pupil will be able to :

- select the spots for texture determination;
- determine approximate textural class of the soil.

Grade

The teacher should evaluate the pupil for the above abilities



Fig. 7.5.1 FORMS A LONG RIBBON FROM A BALL OF MOISTENED SOIL

- If the ball turns into a ribbon easily and remains long and flexible upon pressing, the sample is probably clay or silty clay and is considered heavy or fine textured soil. Such soils are sticky and plastic (retaining the shape given to it).
- If ribbon forms but breaks into 2 to 2.5 cm long pieces (Fig. 7.5.2), the soil is moderately fine textured that is either clay loam or silty clay loam and is moderately sticky and plastic.



Fig. 7.5.2 FORMS A RIBBON BUT BREAKS INTO PIECES

- When a long ribbon is not formed and the ribbon breaks into pieces of less than 2 cm (Fig. 7.5.3), it is probably silt loam, sandy loam or loam. The soil is medium textured or moderately coarse textured.

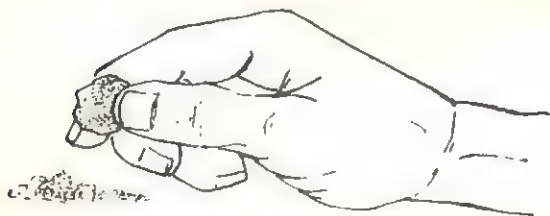


Fig. 7.5.3 RIBBON DOES NOT FORM AND THE SOIL FEELS VERY GRITTY

- If the soil feels smooth and talc like, with no grittiness and silt predominates, the soil is medium textured. If it feels slightly gritty, yet fairly smooth and talc like, it is probably a loam or silt loam and can be included in medium textured group.
- If the sample feels extremely gritty without any smoothness, it is sandy or moderately coarse textured.
- If the sample almost consists of gritty material and leaves no stain on the hand (Fig. 7.5.4), it is a coarse textured soil or sandy soil.



Fig. 7.5.4 SAMPLE CONSIST OF GRITTY MATERIAL AND LEAVES NO STAIN ON THE HAND

7.6 Observations :

The pupil should go round the field and observe the following physical characteristics:

- i. Colour
- ii. Approximate depth of the soil
- iii. Sloppiness
- iv. Feel when dry
- v. Feel when moist (grittiness talc like smoothness)
- vi. Formation of ribbon and its stability
- vii. Texture

7.7 Expected behavioural outcomes :

The pupil will be able to :

- select the spots for texture determination;
- determine approximate textural class of the soil.

Grade

The teacher should evaluate the pupil for the above abilities.

Note : Proficiency in feel method can be attained only through practice with known samples belonging to distinct textural groups. While evaluating, the teacher should also consider the actual textural class of the soil determined by the triangle diagram after mechanical analysis by the hydrometer method.

7.8 Questions :

- i. What are the advantages and shortcomings of determination of texture by feel method ?
- ii. Why a clay rich soil gives sticky feeling when moist?
- iii. What is meant by plastic nature of a soil?
- iv. Which of the soil separates is most important for ribbon formation and why?

8. Activity Unit

STUDY OF A TYPICAL SOIL PROFILE

8.1 Instructional objectives :

The pupil should be able to :

- identify the various horizons of the exposed profile;
- appreciate horizon differentiation of the profile due to various processes, example additions (illuviations), losses (eluviations), transformations, translocation, etc.;
- explain that soil profile provides information for soil classification, nutrient availability, root penetration, etc.

8.2 Relevant information :

8.2.1 *Soil Profile and Horizons*

The vertical section of the soil from the surface normally extending into the parent material is called a soil profile. Each soil profile has a sequence of different layers, known as horizons. A soil horizon may be defined as a layer (of varying thickness) approximately parallel to the soil surface. It has distinct characteristics due to various soil forming processes.

8.2.2 *Differentiation of horizons in the profile*

The horizons in a profile (Fig. 8.2.1) can be designated as follows:

- a) The organic horizon on the top is called 'O' horizon which is formed above the mineral soil. This results from the addition of any organic matter like litter derived from plants, roots, rootlets, dead bodies of insects, animals, etc. This layer ordinarily occurs in cool, humid temperate, and subtropical climates.
- b) The 'A' horizon (zone of eluviation) is the mineral horizon which lies below 'O' near the surface and is characterised usually as the zone of intensive leaching.

- c) The 'B' horizon (zone of illuviation) occurs immediately below the 'A' horizon in which maximum accumulation of materials such as iron and aluminium oxides, salts and clays has taken place. These might have been washed down from upper horizons. This is the zone of accumulation. The 'A' and 'B' horizons together are called the 'Solum'. These are further divided into A_1 , A_2 , A_3 , B_1 , B_2 , and B_3 horizons depending upon the identifying characters. The A_3 and B_1 are the transition horizons between A and B, B and C horizons, respectively. This portion of the profile is developed by the soil forming processes and is distinguished from the parent material immediately below it.
- d) The 'C' horizon is the parent material underlying the solum. It is less weathered than the solum and consequently has no horizon differentiation. However, in certain cases like alluvial soils, black soil, the horizon differentiation may not be there. The 'R' layer is the underlying consolidated bed rock but in alluvial soils this is not likely to be present.

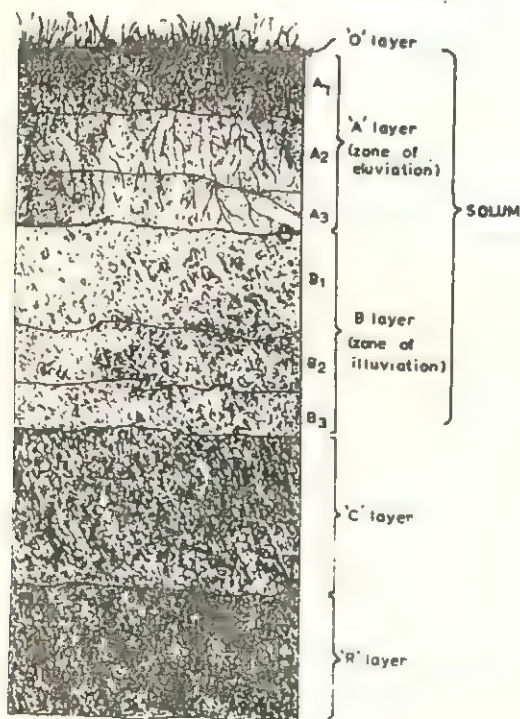


Fig. 8.2.1 A THEORETICAL MINERAL SOIL PROFILE

8.2.3 Why profile study is important ?

The sequence of horizons with different properties is a record of what has happened to that soil since it began to form. This history of formation has relevance to the fertility, tilth and capacity of the soil to produce plants useful to mankind. The specific properties and horizon sequence that a soil acquires in the process of its development are determined by the nature of parent material from which it develops and by the influence of soil forming factors such as climate, topography, and vegetation. These factors act over a period of time to transform the weathered parent material into soil.

8.3 Precautions :

- Expose the profile at such a place that it is representative of the soil of that area.
- Do not expose it at elevated or depressed locations in the field or in a direction directly facing the sun.
- Dig the profile at such a location that maximum visibility is obtained.
- Remove the plant cover, if any, before digging the pit. Do it in a manner so that the soil surface is not disturbed.
- Mark the soil sample bags properly indicating location, depth, horizon details, etc.
- Dig the profile pit in such a way that one side of it has steps for movement of the personnel.

8.4 Materials required :

- i. *Khurpi*
- ii. Spade/pickaxe
- iii. Soil sample bags
- iv. Measuring scale
- v. Test tubes
- vi. Dilute hydrochloric acid
- vii. Phenolphthalein/universal indicator
- viii. Wash bottle (with distilled water)
- ix. Profile description sheets
- x. Indicator papers
- xi. Munshell's colour chart

8.5 Procedure :

- Dig out a pit of the size 2 m x 2 m to a depth of 2 m or up to the parent material. Provide steps, if necessary, on one side for getting into the pit.
- Identify the horizons of the profile on that side of the pit which receives the maximum daylight.
- Demarcate the horizons so that samples can be taken for laboratory study.
- Examine each horizon of the profile in the field for thickness, effervescence, colour and texture using measuring scale, dilute hydrochloric acid, standard colour chart and by feel, respectively.
- Also make observations for soil structure, iron and lime concretions, mottlings, presence of clay, clay skins, salts, roots, undecomposed organic matter, etc.
- Record the observations in the profile description sheet.
- Collect the soil samples in marked sample bags by making a vertically uniform slice of soil for further examination in the laboratory.
- If the horizons are not properly differentiated as in case of alluvial and black soils, examination of the profile should be done at depth intervals of 15 cm down to 1 m depth and thereafter at intervals of 50 cm up to 2 m or to the parent material whichever occurs earlier.

8.6 Observations :

The pupil should study the following properties and note down the observations horizon or layer wise in the profile description sheet.

<i>Properties</i>	<i>Horizons</i>					
	<i>A₁*</i>	<i>A₂*</i>	<i>A₁*</i>	<i>B₁**</i>	<i>B₂**</i>	<i>B₃**</i>
i. Thickness				..		
ii. Colour				..		
iii. Presence of undecomposed organic matter				..		
iv. Texture				..		
v. Structure/compactness***				..		
vi. Presence of roots				..		
vii. Presence of clay/				..		
viii. Effervescence				..		
ix. Reaction to phenolphthalein/universal indicator				..		
x. Other visible characteristics				..		

- Sub-layers of 'A' horizon •• Sub-layers of 'B' horizon
- *** - Structure is the arrangement of primary particles in a definite shape with certain amount of aggregate stability and usually described as single grain, massive, columnar, cube like, platy structure.

8.7 Expected behavioural outcomes :

The pupil will be able to :

- select suitable site;
- identify the horizons;
- make correct observations of the profile characteristics;
- comment on the various processes which should have caused profile differentiation.



The teacher should evaluate the pupil for the above abilities.

8.8 Questions :

- i. Define a soil profile.
- ii. Name the processes which cause profile differentiation
- iii. Name the factors of soil formation
- iv. What is a solum?
- v. How is 'C' horizon different from 'A' and 'B' horizons?
- vi. What is meant by eluviation and illuviation?
- vii. How does an alluvial soil profile differ from the normal profile characteristics?
- viii. What do you mean by young, immature and mature soil?
- ix. What character of the soil is indicated by the effervescence to dilute acid?

9. Activity Unit

DETERMINATION OF FIELD CAPACITY OF SOIL

9.1 Instructional objectives :

The pupil should be able to :

- explain the importance of moisture level in the soil at field capacity;
- determine field capacity of soils;
- recall the factors which affect field capacity.

9.2 Relevant information :

9.2.1 *What is field capacity ?*

Field capacity is the percentage of water that a soil will hold after it has been saturated with water and allowed to drain under tension of dry soil below. Soils generally adjust to this condition 2 or 3 days after heavy rain or soaking irrigation. It would remain at about the same water content if water is not lost by plant removal and or evaporation. At this moisture content, macro pores get drained of water which is retained only in micro pores. The moisture is supposed to be held in the soil with a tension equivalent to 0.33 bar (1/3 atmosphere). The percentage of water at this tension varies with texture of the soil. It thus gives an estimate of the actual amount of moisture which a soil will retain after the field receives sufficient water through irrigation or rainfall.

9.2.2 *Factors affecting field capacity*

The field capacity is influenced by several factors but the most decisive one is the pore size distribution which is a function of bulk density, soil texture and structure. In soils dominated by large pores (example grata sandy or coarse textured), water infiltrates rapidly but a major part of it is lost by drainage (gravitational water) and the proportion of water retained in the soil at field capacity is small. On

the other hand, in soils dominated by micro pores (example gratic clay soils), water infiltrates slowly but the amount of water retained at field capacity is quite high.

9.2.3 Significance of field capacity

Being a measure of the amount of water which may be retained in the soil after rainfall or irrigation, it provides a rough estimate of the potential supply of water to plants. It also helps to know the suitability of the soil for cultivation and to indicate the need for irrigation. Generally, the soil is tilled when the moisture content is one half of the field capacity. When moisture content is above the field capacity level, the soil is too moist and is liable to structural damage on cultivation such as forming large clods.

9.3 Precautions :

- Select a site of $2\text{m} \times 2\text{m}$ where water table is not within two metre from the layer from which field capacity is to be determined.
- Remove all grasses and weeds and level the area of the selected site.
- Cover the area properly so that evaporational loss is prevented.

9.4 Materials required :

- i. Straw, tarpaulin or polythene sheet
- ii. Moisture box
- iii. Balance with weight box (physical)
- iv. Oven
- v. Spade
- vi. Tube auger
- vii. Desiccator

9.5 Procedure :

- Select a representative spot in the field.
- Bund the area measuring $2\text{m} \times 2\text{m}$ on all four sides (Fig. 9.5.1) using a spade.
- Clear the grasses, weeds etc. and level it.
- Add enough water to saturate the soil down to the depth of interest but not less than 15-20 cm (Fig. 9.5.2).

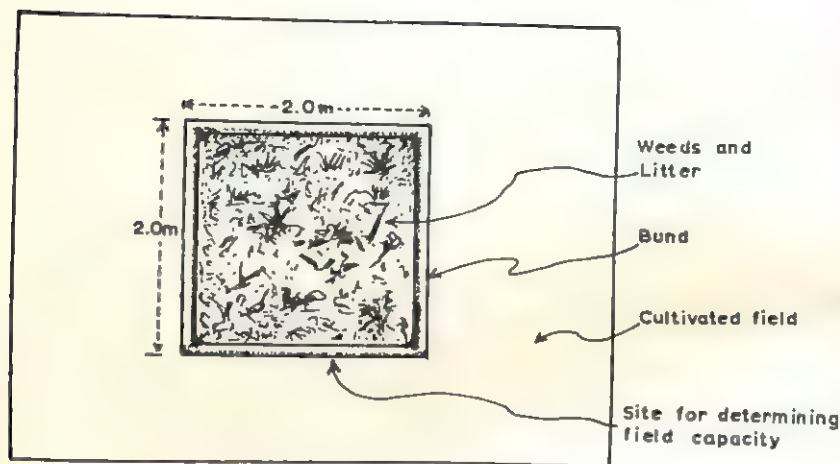


Fig. 9.5.1 SITE WITH BUND

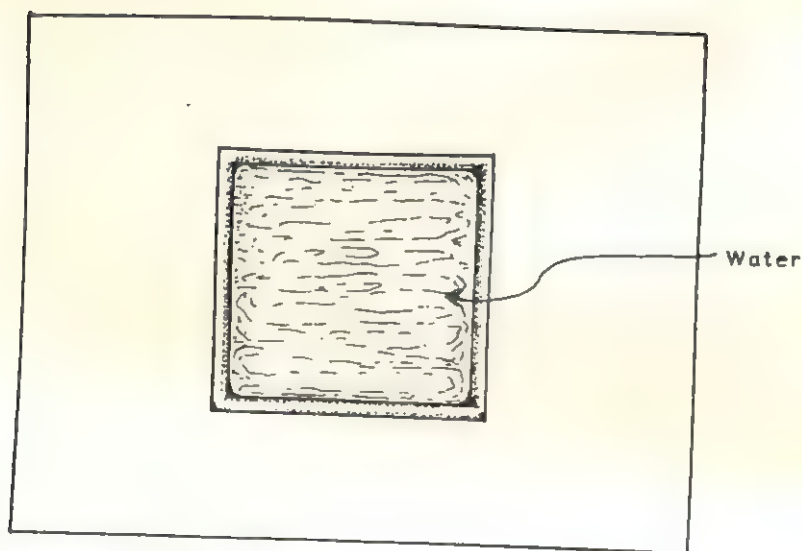


Fig. 9.5.2 CLEAN SITE FILLED WITH WATER

— Cover with a polythene sheet or tarpaulin to prevent evaporation (Fig. 9.5.3); alternatively spread straw to have at least 30 cm thick cover.

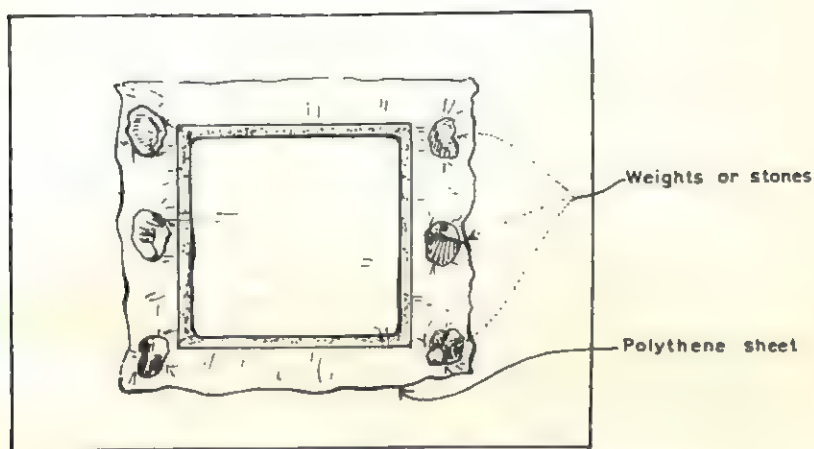


Fig. 9.5.3 SITE COVERED WITH POLYTHENE SHEET

- After 48 to 72 hours, collect two soil samples with a tube auger at 15 cm depth or at any depth of interest (Fig. 9.5.4) and transfer each sample in a moisture box for determination of soil moisture.

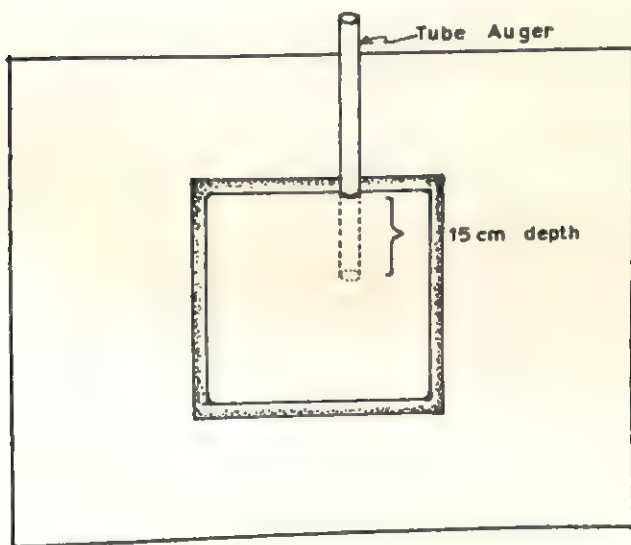


Fig. 9.5.4 SOIL SAMPLING WITH TUBE AUGER

9.6 Observations :

The pupil should take the following weights:

- i. Weight of moisture box with moist soil = W_1
- ii. Weight of moisture box with soil after = W_2
oven drying

9.7 Calculations :

The pupil should calculate the field capacity by the following expression :

$$\text{F.C. (\% dry weight)} = (W_1 - W_2) / W_2 \times 100$$

9.8 Expected behavioural outcomes :

The pupil will be able to :

- explain the significance of field capacity determination;
- select the site for field capacity determination;
- undertake bunding and removing of weeds from the site;
- saturate the site with water;
- check evaporation from the soil;
- collect the soil sample from the site;
- weigh accurately;
- calculate the field capacity.

Grade

The teacher should evaluate the pupil for the above abilities.

9.9 Questions :

- i. How is field capacity influenced by clay content?
- ii. Why is field capacity referred to as the upper limit of water availability?
- iii. Why the tillage operations normally should not be done when moisture content of the soil is above the field capacity?
- iv. At what force the water is held at field capacity?
- v. What are the factors affecting field capacity?
- vi. When do the soils reach field capacity?
- vii. Which of the following soils will retain more moisture at the field capacity ? (Arrange in a decreasing order)

- a) Sandy clay loam
 - b) Loam
 - c) Clay loam
 - d) Silty clay loam
- viii. Why field capacity can not be determined immediately after rainfall or irrigation?

10. Activity Unit

DETERMINATION OF SATURATION CAPACITY OF SOIL

10.1 Instructional objectives :

The pupil should be able to :

- explain the importance of saturation capacity;
- determine saturation capacity of the soil;
- appreciate why the value of saturation capacity is greater than that of porosity and field capacity.

10.2 Relevant information :

10.2.1 *What is saturation capacity?*

The saturation capacity is the amount of water held by a soil when it is completely saturated with water. At this moisture content, all macro and micro pores of the soil are filled with water and water is retained in soil without any tension (bar). Since saturation capacity includes water retained in pore spaces and that adsorbed by the soil solids, it is usually greater than porosity. In case the air remains entrapped in the soil which will not allow entry of water, the value may be lower than that of porosity. If large amount of salts are present in the soil, they would dissolve resulting in decrease in saturation capacity.

10.2.2 *What is the significance of saturation capacity?*

Saturation capacity expressed as percentage (by weight) gives an approximate idea of total porosity. Some approximation of field capacity can be made from saturation capacity. For instance, saturation percentage is roughly twice the field capacity. Since the soil is devoid of air, the plants growing under saturated soil condition suffer from oxygen deficiency. Saturation percentage is also useful as salinity (soluble salt content) of soil is usually measured at this moisture level.

10.2.3 How it is determined?

Saturation percentage is determined in the laboratory with a Keen's box using processed soil samples. In this method, soil is steadily saturated by capillary action allowing for the escape of air from within the soil pores.

10.2.4. What is Keen's box?

It is a metallic (brass) cylindrical dish having internal diameter of 5.6 cm and height of 1.6 cm (Fig. 10.2.1) The bottom of the box is perforated with holes 0.75 mm in diameter and 4 mm apart.

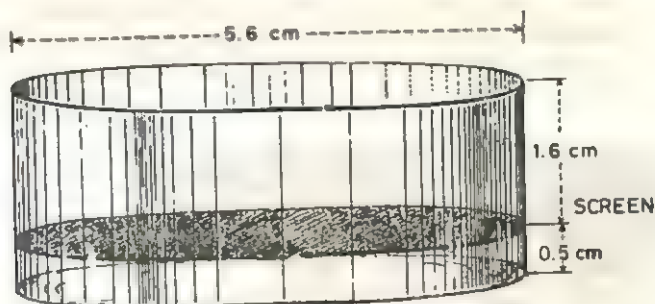


Fig. 10.2.1 A KEEN'S BOX

10.3 Precautions :

- Pack the soil uniformly in the Keen's box. Carefully scrap the excess soil over the entire surface of the box with the help of flat knife (spatula).
- Saturate the soil till a thin layer of water appears on the surface.

10.4 Materials required :

- i. Keen's box
- ii. Filter paper
- iii. Watch glass
- iv. Balance with weight box
- v. Tray
- vi. Desiccator
- vii. Oven
- viii. Spatula or flat knife

10.5 Procedure :

- Use air dry sample, ground and passed through a 2 mm sieve.
- Take a Keen's box and place a filter paper of the appropriate size on its perforated bottom.
- Place the Keen's Box on a watch glass and weigh it.
- Transfer the soil in small lots (5-6 g) by means of a spatula and tap the box gently, 4-5 times, on a plain wooden table to attain uniform packing with each addition of soil and continue the process till the box is filled a little over the top edge. Slice off excess soil with the help of a spatula.
- Tap the box, add a little more quantity of soil and again remove the excess soil to obtain a levelled surface.
- Place the box in a tray containing water at a level almost 0.5 cm above the perforated bottom of the Keen's box (Fig. 10.5.1).

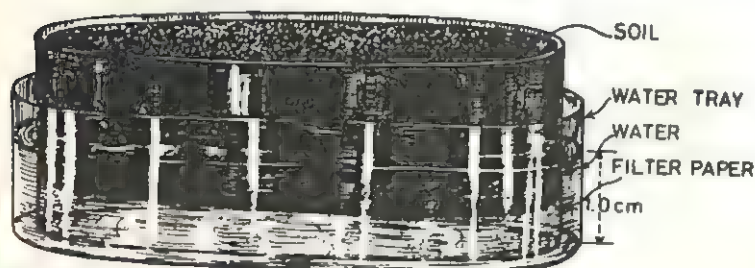


Fig. 10.5.1 FILLED KEEN BOX KEPT FOR SATURATION IN WATER TRAY

- Allow it to saturate till a glistening film of water is observed at the soil surface. About 12-16 hours of capillary wetting would be needed to ensure complete saturation of fine textured soil. Saturation of a coarse textured soil is achieved in a shorter time.
- Remove the box from the tray, place it on the table for a short while to drain the excess water, wipe the side of the box and bottom with a filter paper, place it on the same watch glass and weigh it.
- After weighing, place the box in an oven and dry it at 105°C to constant weight.
- Cool the box in a desiccator and weigh on the watch glass.
- Weigh ten filter papers of the size placed on the bottom of the Keen's box, saturate them with water, roll a glass rod gently over them to squeeze out the water uniformly, weigh the wet

filter paper and calculate the average amount of water held by one paper.

10.6 Observations :

The pupil should take and record the following :

- Weight of watch glass plus box containing filter paper = a g
- Weight of watch glass plus box containing saturated soil = b = g
- Weight of watch glass plus box containing soil after oven drying = c g
- Average weight of water held by a filter paper = d g

10.7 Calculations :

The pupil should calculate the saturation capacity by using following expression :

$$W_s = \frac{b - (c + d)}{(c - a)} \times 100$$

Saturation percentage by weight (W_s) can be converted to saturation percentage by volume (V_s) on multiplying it by bulk density of the soil.

10.8 Expected behavioural outcomes :

The pupil will be able to :

- weigh accurately;
- explain the method of packing the soil;
- identify the point of water saturation of the soil;
- recall the dimension of Keen's box;
- estimate the bulk density of the soil packed in the Keen's box.

Grade

The teacher should evaluate the pupil for the above abilities.

10.9 Questions :

- i. Why saturation capacity is not necessarily equal to total pore space?
- ii. How is the value of saturation percentage affected by the presence of soluble salts in the soil?

- iii. Why are ten filter paper pieces used to determine the amount of water absorbed by a filter paper?
- iv. What are the advantages of capillary wetting of the soil?
- v. Why filter paper is placed at the bottom of the Keen's box?
- vi. Why clay soils retain more water than sandy soil?
- vii. Why after saturation with water the top layer of the clayey soil rise more than the level of a sandy soil?

11. Activity Unit

DETERMINATION OF INFILTRATION RATE OF SOIL

11.1 Instructional objectives :

The pupil should be able to :

- realise the significance of infiltration rate of water from the standpoint of soil and water management;
- determine infiltration rate of the soil;
- explain why the rate of infiltration decreases with time.

11.2 Relevant information :

11.2.1 Infiltration

Infiltration refers to the entry of water into the soil in any direction. The speed at which water enters into the soil is expressed as infiltration rate (usually as cm/ hr) or water intake rate. It is rapid in the beginning and decreases with time as the pores get filled with water and soils adsorb moisture, attaining almost a steady state which is called infiltration capacity or basic infiltration rate.

11.2.2 Factors affecting infiltration rate

Infiltration rate is influenced mainly by soil physical conditions namely, texture, structure, moisture content, presence or absence of swelling type of clays and depth and to impermeable layer.

11.2.3 Significance of infiltration rate

Infiltration capacity of a soil influences the point at which run-off (flow of water over land surface) takes place. In the soil with a low infiltration capacity, run-off occurs even at low rainfall intensity and thus, dangers of loss of top soil due to erosion are great. Infiltration rate also influences the choice of irrigation method and design. For sprinkler irrigation, rate of application is planned in such a way that it is not higher than water intake rate. Infiltration rate also reflects the

structural condition of a soil and one has to think of suitable soil management practices (such a improving structural condition), if infiltration rate is either very rapid or very slow.

Classification of soil on the basis of infiltration rate :

<i>Class</i>	<i>Infiltration rate (cm/hr)</i>
Very rapid	> 25.4
Rapid	12.7 — 25.4
Moderately rapid	6.3 — 12.7
Moderate	2.0 — 6.3
Moderately slow	0.5 — 2.0
Slow	0.1 — 0.5
Very slow	< 0.1

11.2.4 Methodology

The infiltration rate is usually measured under field conditions so that the results can be of direct relevance in soil-water management. The method involves ponding of water on the soil surface or sprinkling to simulate the rain. While there is no generally accepted procedure applicable to all situations, the ring infiltrometer method involving ponding of water is the most versatile one of the various techniques available. A guard ring is needed to check the lateral movement of water which otherwise will make the determination unreliable. The rate at which the level of ponded water surface recedes gives an estimate of infiltration rate with time.

11.3. Precautions :

- Avoid puddling of soil during addition of water.
- Push both the rings exactly vertically to the same depth in the soil.
- Check against any lateral movement of water.
- Keep the same water level in the inner ring as well as in the guard ring.

11.4 Materials required :

- i. Two metal rings—inner one of 30 cm diameter and 20 cm height and outer guard ring of 50 cm diameter and 20 cm in height. One edge of these rings should be sharpened so as to facilitate easy penetration into the soil (Fig. 11.4.1.)
- ii. Hammer large, preferably wooden

- iii. Watch
- iv. Spade
- v. Driving plate—steel plate about 1.5 cm thick and 60 cm in diameter
- vi. Gunny bag piece



Fig. 11.4.1 INFILTRATION APPARATUS

11.5 Procedure:

- Remove or clean the surface litter without disturbing the soil.
- Place the apparatus on the cleaned surface (Fig. 11.5.1).

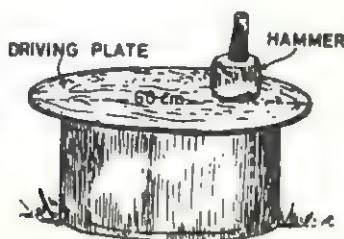


Fig. 11.5.1 APPARATUS READY FOR PENETRATION

- Drive the inner and guard rings (Fig. 11.5.2) vertically and parallel to one another in the soil by hammering on the driving plate placed on the rings until the top 10 cm of the

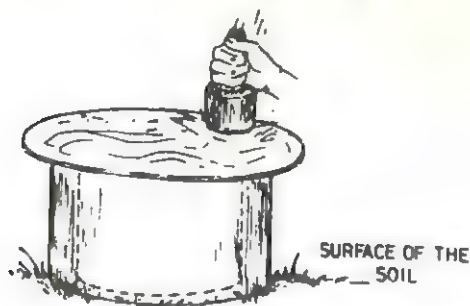


Fig. 11.5.2 RINGS BEING DRIVEN INTO THE SOIL

- rings remain above the soil surface.
- Place the gunny bag piece on the soil surface of the inner ring.
 - Pour water inside and outside the inner ring so that water is ponded to a depth of 6 cm (Fig. 11.5.3).



Fig. 11.5.3 WATER IN EXPOSED PORTION OF THE RINGS

- Record the initial level and continue recording the receding water level in inner ring after suitable intervals of time, say after every 5-15 min depending upon the rate of entry of water into the soil.

11.6 Observations:

The pupil should take and record the following observations:

<i>Time after infiltration commenced (minutes)</i>	<i>Depth of water infiltrated (mm)</i>	<i>Rate of infiltration (mm/hr)</i>
2		
5		
10		
15		
30		
60		
90		
120		

11.7 Calculations:

The pupil should calculate the rate of infiltration by preparing a graph in two dimension curves that is time on one axis and the depth of water infiltrated on the other.

11.8 Expected behavioural outcomes :

The pupil will be able to :

- explain the methodology;
- insert the rings correctly;
- record the readings and determine the infiltration rate;
- explain the changes in the rate of infiltration with time.

Grade

The teacher should evaluate the pupil for the above abilities.

11.9 Questions:

- i. Why does the rate of infiltration decrease with time?
- ii. What is the effect of initial moisture content of the soil on the rate of infiltration?
- iii. What is the influence of soil texture on the infiltration rate of water?
- iv. Can the infiltration rate of water in a clay soil be improved? If so, how?
- v. How does the rate of infiltration affect the run-off during rainfall?
- vi. Has infiltration rate any relationship with the capacity of the soil to retain water?
- vii. How the choice of irrigation methods and time can be decided on the basis of the rate of infiltration?
- viii. Why two rings are required to measure infiltration rate? Why the space between the two is also to be filled with water?

12. Activity Unit

STUDY OF SOIL-WATER RELATIONSHIP

12.1 Instructional objectives :

The pupil should be able to :

- determine soil moisture content by weight as given earlier under Sub Unit 2b, and convert it to volumetric moisture content and into depth term;
- relate water retentivity and potential water availability to soil texture;
- explain why field capacity is taken as the upper limit of water availability;
- interpret irrigation requirement of crops growing on soils of varying texture;
- interpret drainage conditions of soils.

12.2 Relevant information :

12.2.1 Soil moisture content

As already described before (Sub Unit 2b), the weight loss of soil on drying at 105°C (to constant weight) gives a measure of the moisture content which is expressed as percentage of the oven dry weight of the soil. Moisture content by weight (ΘW) can be converted to that by volume (ΘV) according to the relationship: $\% \Theta V = \Theta W \times D_b$ where: D_b is the bulk density of the soil.

For all practical purposes, such as to estimate the amount of water stored in the soil profile, the amount of moisture depletion in the profile or the quantity of irrigation water needed to make up the depletion, it is necessary to convert the moisture content into depth term (Θ depth in cm). This is done by using the relationship:

$$\Theta \text{ depth} = \Theta V \times d$$

where, ΘV is the volume of water per unit volume of soil and d the soil depth (cm). Based on Θ depth values, depth of irrigation

water required before depleting soil moisture can be calculated for a given depth of soil.

12.2.2 Moisture retention in soil

Water is held in soil on solid particle surfaces by adhesion and in the pores by matric forces. The forces of adhesion and cohesion (between water molecules themselves) are at a maximum near the particle surface. With increasing distance from the walls of the soil pores, these forces decrease and become negligible at a distance of about 0.06 mm. Hence, water molecules farther than 0.06 mm from the particle surface are not affected by matric forces and therefore these are free to move through the soil towards downward direction because of gravitational force. It is for this reason that water moves freely (without any tension) through macropores under the influence of gravity. Within the micropores, some quantity of water is held very tightly (at a high tension) to the soil particles and it is almost immobile. This is called hygroscopic water. Therefore, the soil moisture can be classified as, hygroscopic water, capillary water (held less tightly in micropores) and gravitational water (free moving).

12.2.3 Plant available water

As water is essential for plant growth, a biological classification (in relation to plant behaviour) of soil water has been made. This divides the soil moisture content into two classes namely, water which is available to plants and that which is unavailable. The water not available to plants includes two components: gravitational water cannot be taken up by plants because it drains too rapidly; hygroscopic and part of the capillary water are not available because these are held too tightly within the soil to be extracted by plant roots. Therefore, the water actually available to plants is confined to a relatively narrow range of soil moisture which at the wet end is field capacity and at the dry end is delineated by wilting point, corresponding to 1/3 bar and 15 bar (or atmosphere) moisture tension, respectively. Whereas field capacity gives an indication of the potential supply of water to plants, wilting point indicates the stage at which plants show evidence of permanent wilting (not restorable by supplying water) due to severe lack of moisture.

12.2.4 Soil type and water retention

Sandy soils have a high proportion of macropores. Hence, rain or irrigation water infiltrates rapidly. Since the proportion of

micropores is small, these soils have low water retention capacity and would need frequent irrigation for raising good crops. Heavy irrigation will be a wasteful practice.

Medium textured or loamy soils retain more moisture. Since the fine clay and silt in these soils are usually aggregated, water enters readily through the macropores between the coarser particles and the aggregates and is retained in micropores within the aggregates. The soil aggregates (not clods) should be sufficiently stable not to crumble down in contact with water.

Clay soils have high proportion of micropores and a large surface area. Hence, these soils can hold maximum amount of water. However, they are often not well aggregated and so water infiltrates very slowly. Run-off losses of water result even under normal rainfall condition and more so when there is a slope.

12.3 Precautions :

- Use at least three soils varying widely in texture.
- Fill only that much soil in the can which can be accommodated even after its likely swelling on wetting.
- Keep the cans away from direct sunlight to minimise evaporation loss.

12.4 Materials required :

- i. Three soils of varying texture and washed gravels
- ii. Empty 4 kg circular cans (normally used for edible oils)
- iii. Moisture boxes
- iv. Measuring cylinder
- v. Glass or polythene vessels (to collect drainage water)
- vi. Polythene sheet
- vii. Tube auger
- viii. Pan balance and weight box
- ix. Oven
- x. Measuring scale

12.5 Procedure :

- Take three empty and clean cans (4 kg size) and make a drainage hole of 1.25 cm (approx.) diameter in the side near the bottom in each.
- Place a layer of washed gravel 2.5 cm in thickness at the bottom.

- Fill a container with one type of soil free from extraneous matter. Fill three such containers with three separate soils viz. sandy, loam and clay soils (Fig. 12.5.1) to not more than $\frac{2}{3}$ rd of the height of the can.

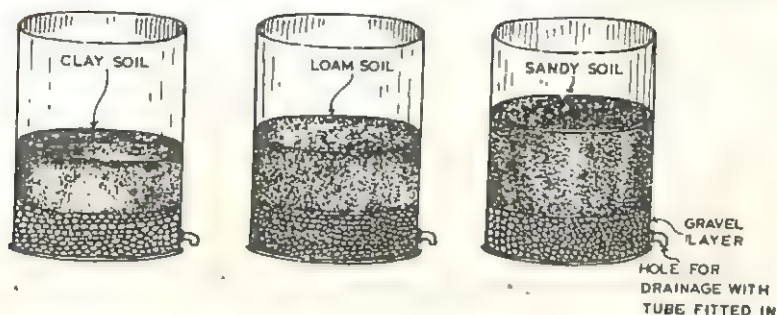


Fig. 12.5.1 CANS WITH DIFFERENT SOILS

- Add soil in small amounts and tap 5 times with the addition of each increment. Keep a record of the amount of soil in each container.
- Measure the height and diameter of the soil column in each can for knowing the volume.
- Use a representative sample of each soil for moisture determination (Sub Unit 2b).
- Add water slowly (without disturbing the surface) in each of the containers in small increments till the soil gets fully saturated which will be known when drainage of water begins (In case of clay soils this may take several hours).
- Record the time during which the applied water completely infiltrates into the soil. Keep account of the water added in each container.
- Add more water to the surface and collect drained water at an interval of one hour. Continue it for 2 hours or more if needed.
- Measure the amount of water drained from each container during an interval of one hour.
- Cover each can with a polythene sheet to prevent evaporation and leave aside for 2 days.
- Remove the polythene cover and determine the depth of soil column after taking into account the thickness of the gravel layer.
- Collect the soil sample with a tube auger and determine

moisture content by oven drying it at 105°C to constant weight. This will give an estimate of the field capacity of the disturbed soil.

12.6 Observations :

The pupil should take and record the following observations :

	<i>Sandy soil</i>	<i>Loam soil</i>	<i>Clay soil</i>
i. Soil filled in the container			
A) Air dry soil (Kg)	—	—	—
b) Moisture (%)	—	—	—
c) Oven dry soil (Kg)	—	—	—
ii. Bulk density of soil in the container (g/cc)	—	—	—
iii. Amount of water applied till outflow through drainage hole commences (cc)	—	—	—
iv. Amount of water added to saturate the soil, expressed in percentage	—	—	—
v. Time taken for infiltration of a given increment of water per minute			
1st Increment	—	—	—
2nd Increment	—	—	—
3rd Increment	—	—	—
Average	—	—	—
vi. Average rate of infiltration (cm/hr)	—	—	—
vii. Amount of drainage (cc)			
1st hour	—	—	—
2nd hour	—	—	—
Average	—	—	—
viii. Average rate of water movement through soil (cm/hr)	—	—	—
ix. Field capacity moisture in the test samples			
θ _w (%)	—	—	—
θ _v (%)	—	—	—
θ depth (cm)	—	—	—

12.7 Expected behavioural outcomes :

The pupil will be able to :

- determine the texture of the three soils by feel method;

Grade

- estimate the following on the basis of observations collected :
 - a) bulk density of the soil sample
 - b) rate of infiltration of water
 - c) appropriate saturation percentage
 - d) rate of water movement
 - e) moisture at field capacity (Potential water availability);
- relate water retentivity, rate of infiltration, rate of water movement and potential water availability to clay content;
- infer irrigation requirement of crops on these soils;
- interpret drainage conditions in these soils.

The teacher should evaluate the pupil for the above abilities.

12.8 Questions :

- i. Why do the crops growing on sandy soils require frequent irrigation?
- ii. Why is it advisable to apply light irrigations on sandy soils?
- iii. Why excess water application on a heavy (clay) soil leads to run-off loss?
- iv. What is plant available water?
- v. What is meant by permanent wilting point?
- vi. What is matric force?
- vii. What is hygroscopic water?
- viii. Why does a clay soil retain more water?
- ix. Why is gravitational water not available to plants?
- x. How water from below rises to the surface soil against the force of gravity?
- xi. How is field capacity of a sandy soil likely to be influenced after it is compacted?
- xii. What is the influence of soil structure on water retention?

13. Activity Unit

DETERMINATION OF SOIL pH

13.1 Instructional objectives :

The pupil should be able to :

- explain the meaning and significance of soil reaction and pH;
- use pH strips and indicator solutions for the determination of pH;
- handle pH meter;
- predict the availability of plant nutrients in the soil in relation to its pH value.

13.2 Relevant information :

13.2.1. What is pH?

pH is a measure of the acidity or alkalinity of a material. It is defined as the negative logarithm of hydrogen ion activity. Mathematically, $\text{pH} = -\log_{10} (\text{H}^+)$, where (H^+) is the activity of hydrogen ions in moles/litre. (In dilute solutions, activity is practically equal to the concentration in moles per litre).

13.2.2 pH scale and its importance

Pure water is weakly dissociated into H^+ and OH^- ions according to the following equation;



According to the law of dissociation

$$[\text{H}^+] \times [\text{OH}^-] / \text{H}_2\text{O} = K$$

where: H^+ etc are the concentrations and K is the dissociation constant. Since the concentration of undissociated water remains practically the same, because of very little ionisation of H_2O molecule the above relationship becomes:

$$[\text{H}^+] \times [\text{OH}^-] = K_w = 10^{-14} \text{ at } 20^\circ\text{C}$$

K_w : ion product constant of water.

At neutrality, $H^+ = OH^-$ and $H^+ = 10^{-7}$ or pH 7. Pure water has a pH value of 7. As the hydrogen ion activity increases (say on adding any acid), the pH value will decrease while it will go up with the rise in hydroxyl ion activity. pH scale thus, extends from 0 to 14 at the temperature stated above.

Mid-point on this scale represents neutral reaction. pH above 7 denotes alkalinity and below 7 acidity. pH of a soil is an important physico-chemical characteristics because it influences:

- suitability of soil for crop production,
- availability of soil nutrients to plants (Fig. 13.2.1),
- microbial activity in the soil (Fig. 13.2.1),
- lime and gypsum requirement of soil,
- physical properties of soil like structure, permeability, etc.

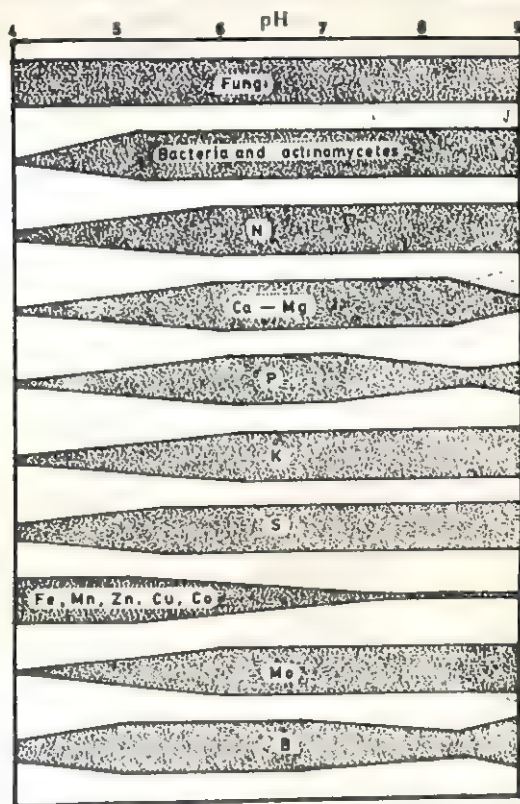


Fig. 13.2.1 MICROBIAL ACTIVITY AND NUTRIENT AVAILABILITY IN RELATION TO pH. THE WIDTH OF STRIPS INDICATE THE EXTENT OF MICROBIAL ACTIVITY AND THE AVAILABILITY OF NUTRIENTS

13.2.3 Methods of pH determination

There are two methods by which pH can be determined:

- (a) pH strips/pH indicators, and
- (b) pH meter.

13a. Sub Unit: Determination of pH by Indicators or Strips

13a.1 Relevant information :

13a.1.1 Principle

pH indicators contain organic dyestuffs which have the property of changing colour with change in hydrogen (or hydroxyl) ion concentration of the system. Barium sulphate helps in the settling of colloidal particles in a soil suspension so that the indicator colour can be judged and its quantity required depends on the extent of colloidal material present.

pH-strips, bearing narrow pH ranges are readily available. pH strips coated with indicators are sensitive to hydrogen ion concentration and are differently coloured in solutions differing in acidity/alkalinity.

The range of pH values, within which the pH strip or indicator solution changes colour varies for different indicators as shown below:

<i>Indicator</i>	<i>Colour change</i>	<i>pH range</i>
Bromophenol blue	Yellow-violet	2.8—4.6
Bromocresol green	Yellow-blue	3.6—5.2
Methyl red	Red-yellow	4.2—6.3
Bromocresol purple	Yellow-purple	5.2—6.8
Bromothymol blue	Yellow-blue	6.0—7.6
Cresol red	Yellow-red	7.2—8.3
Thymol blue	Yellow-blue	8.0—9.6

13a.2 Precautions :

- Observe the colour of the strips carefully after dipping in soil suspension and matching with the standard.
- In case indicator is used, observe the final colour of the clear supernatant liquid and match it carefully with the standard.

- Handle the strips/indicator carefully with clean hands avoiding any type of contamination.

13a.3 Materials required :

- pH strips/pH indicators in narrow pH range
- Barium sulphate (extra pure powder)
- Test tubes (20 cm long) with corks

13a.4 Procedure :

- Place a layer of Barium Sulphate (BaSO_4) about 1 cm thick at the bottom of a test tube. If the soil is clayey, take a larger quantity of BaSO_4 .
- Place on it a 3 cm thick layer of soil and fill with distilled water upto the height of 12—15 cm.
- Plug the tube with a cork and shake vigorously for about a minute and allow the contents to settle, till the supernatant liquid is clear.
- Dip the pH strip into soil suspension and note the change in the colour of the strip.
- If indicator solution is used, add 2 or 3 drops in the tube through the sides and allow it to get mixed and see the colour.
- Compare the colour change of the strip/supernatant liquid with the colour chart given on the top flap of each set of strips or on the bottle. If it matches, the pH of the suspension is in the particular range. Note it down. If the colour does not match, take either the upper side or lower side of the strips/indicator and match the colour.

13a.5 Observations:

The pupil should observe the change in colour of pH strips/indicator solution and record the pH.

pH of soil = _____

13a.6 Expected behavioural outcomes :

The pupil will be able to :

- use right type of pH strips, indicator solution;
- compare colour of soaked strips/clear suspension with colour chart available on the pad of pH strips/indicator bottle.

Grade

The teacher should evaluate the pupil for the above abilities.

13b. Sub Unit : Determination of pH by pH Meter

13b.1 Relevant information :

13b.1.1 Principle

The potentiometric determination of pH is based on the measurement of the electrical potential developed by an electrode whose potential depends on the hydrogen ion concentration of the solution. The single electrode potential of any electrode (half cell) should be measured with the second electrode (reference electrode) dipping into the same solution. Glass electrode is the most convenient among different pH electrodes. The reference electrode commonly used is the saturated calomel type. Single combined electrodes are also available with some pH meters. The pH meter measures the voltage developed by the combination of glass electrode and reference electrode and the scale is graduated in pH units as well as in millivolts. The pH meters are to be calibrated using standard buffer solutions.

13b.2 Precautions :

- Dip the electrodes carefully into the test solution without touching the bottom of the container.
- Adjust the temperature knob for the correct temperature.
- Do not allow the electrodes to remain in the test solution or soil suspension longer than necessary.
- Immediately after testing, wash the electrodes with a gentle stream of distilled water.
- After cleaning, suspend the electrodes in distilled water for storage and protect against evaporation.
- Avoid drying of the electrodes.

13b.3 Materials required :

- i. Balance
- ii. Beaker (100 ml capacity)
- iii. Measuring cylinder
- iv. Glass rod
- v. pH meter with electrodes
- vi. Buffer solutions (usually pH 4 and pH 10) or tablets
- vii. Ordinary filter paper
- viii. Washing bottle (with distilled water)

13b.4 Procedure :

- Weigh 20 g of airdry soil into a 100 ml beaker, add 40 ml of distilled water (1 : 2 ratio) and stir briskly at least four times over a 30 minutes period.
- In the meantime, switch on the pH meter and set temperature compensation knob at buffer solution temperature and the range selector to zero.
- After a 10-minute warming up period, bring the galvanometer pointer to zero with the help of zero set knob.
- Dip the electrodes into a buffer solution of known pH, turn the range selector and adjust the reading to the pH of the buffer solution, with the help of the standardisation knob. Check the instrument with two buffer solutions of known pH viz., one acidic and another alkaline.
- Rinse the electrodes with distilled water and carefully wipe with filter paper.
- Shake the soil solution and insert the electrodes into it.
- Turn the selector in the proper pH range and read the pH on the dial of the meter. Turn back selector to zero and take out the electrodes.
- Rinse the electrodes with distilled water and then lower them back into a beaker containing distilled water.

13b.5 Observations :

The pupil should take the pH reading on the pH meter and should record it.

pH of soil (1:2 ratio) = _____

If possible, compare the pH values obtained with strip/indicator and pH meter.

13b.6 Interpretation :

<u>pH</u>	<u>Interpretation</u>
< 6.5	Acidic reaction
6.5—7.5	Normal—no treatment, optimum for most crops
>7.5	Alkaline

Note : If the soil is too acidic, liming is recommended. If the soil is too alkaline, reclamation measures have to be undertaken to obtain good crops.

13b.7 Expected behavioural outcomes :

The pupil will be able to :

- explain the principle of pH determination;
- handle pH meter;
- adjust the pH meter with buffer solutions;
- explain the significance of pH in relation to plant growth;
- interpret the pH data for soil management and suitability of soil for crops.

Grade

The teacher should evaluate the pupil for the above abilities.

13.3 Questions :

- i. Why is it important to know the pH of soils?
- ii. What do you understand by an acidic, neutral and alkaline soil?
- iii. What is the principle underlying potentiometric determination of pH?
- iv. What is the function of BaSO_4 in determination of soil pH by pH strips/indicators?
- v. Why the soil water ratio is kept as 1:2 while determining the pH? Can other ratios be adopted?
- vi. What precautions must be observed in the use of a glass electrode pH meter?
- vii. Why should buffer solution be used for calibration of pH meter?
- viii. Why should the temperature knob be adjusted?
- ix. What is the purpose of using a calomel reference electrode?

14. Activity Unit

DETERMINATION OF TOTAL SOLUBLE SALTS IN SOIL

14.1 Instructional objectives :

The pupil should be able to :

- explain the significance of water soluble salts in soil;
- determine total soluble salts by evaporation method;
- understand the principle of conductivity measurements;
- operate conductivity bridge;
- relate electrical conductivity data to the concentration of total soluble salts present in soils.

14.2 Relevant information :

14.2.1 *What is the importance of this determination?*

The determination of total water soluble salts is of special importance for arid and semi-arid regions and for irrigated areas because soils under these conditions tend to develop salinity or alkalinity due to the accumulation of salts. The nature of ions present determines whether the soil is saline or alkaline (sodic). This will help in taking reclamation measures as well as in the selection of crops which differ in their tolerance to salts.

14.2.2 *What are the major ions present in soil extract?*

The soil extract contains anions like Cl^- , SO_4^{2-} , NO_3^- , CO_3^{2-} , HCO_3^- and cations such as Ca^{++} , Mg^{++} , K^+ and Na^+ .

14.2.3 *Methods for the determination of total water soluble salts in soil.*

Total water soluble salts in soil-water extract (1:2 ratio) may be determined either by evaporation of a known volume of the extract or by electrical conductivity method. The latter one is easier and more widely adopted in practice.

14a. Sub Unit : **Determination of Total Soluble Salts by Evaporation**

14a.1 Relevant information :

— *Principle*

Total soluble salts are determined gravimetrically by evaporating a known quantity of soil-water extract to dryness and weighing.

14a.2 Precautions :

- Use distilled water only for making suspension.
- Shake the suspension thoroughly a number of times.
- Allow the soil suspension to stand for sufficient time so that a clear supernatant liquid is obtained.

14a.3 Materials required :

- i. Shaking bottle
- ii. Mechanical shaker
- iii. Evaporating dish, funnel, conical flask
- iv. Water bath
- v. Oven
- vi. Desiccator
- vii. Chemical balance with weight box
- viii. Hydrogen peroxide (6% or 20 vol.)
- ix. Distilled water
- x. Filter paper (Whatman No. 42)

14a.4 Procedure :

- Transfer 100 g soil into a 750 ml shaking bottle.
- Add 200 ml of distilled water, stopper well and shake it in a mechanical shaker for one hour. In the absence of a shaker, shaking can also be done manually.
- Filter the suspension after the soil settles down.
- Reject first few ml of the extract (if turbid) and collect the clear filtrate for the determination of soluble salts.
- Transfer 50 ml of the extract to a tared (previously weighed) dish and evaporate on a water bath.
- Add 5 ml of 6% of H_2O_2 when the volume of the extract is

- reduced to 2 ml and evaporate further to dryness. Repeat this treatment if the residue is coloured due to the presence of organic matter.
- Dry in an oven at 105°C for one hour and cool in a desiccator and weigh.

14a.5 Observations :

The pupil should take the following observations :

- Weight of the Dish = W_1 g
- Weight of dish + residue after drying = W_2 g.

14a.6. Calculations :

The pupil should calculate the percentage of total soluble salts by the following expressions :

$$\begin{aligned}\text{Percentage of total soluble salts} &= \frac{(W_2 - W_1) \times 200 \text{ ml}}{\text{Volume of extract taken}} \\ &= \frac{(W_2 - W_1) \times 200 \text{ ml}}{50}\end{aligned}$$

Tentative criteria for evaluating total soluble salts (in soil)

<i>Measurement</i>	<i>Method and basis of expressing result in soils</i>	<i>Usual range encountered</i>	<i>Satisfactory range for most plants</i>	<i>High to excess range</i>
Total soluble salts in soil extract	Saturation* expressed in ppm by soil	Less than 100 to more than 3000	Less than 1000	Over 1500
—do—	1:5 soil water extract expressed in ppm by soil	Less than 100 to more than 3000	Less than 1000	Over 1500

* Saturation extract is that obtained after saturating the soil with water and establishing the equilibrium at that particular temperature.

14b. Sub Unit : **Determination of Total Water Soluble Salts using Conductivity Bridge (Solubridge)**

14b.1 Relevant information :

14b.1.1 Principle

The measurement is based on the principle that ions being the carriers of electricity the electrical conductivity of a solution increases with soluble salt concentration. Thus, it is possible to relate electrical conductivity with soluble salt content of the soil.

$$\text{Per cent total soluble salts} = 0.06 \times \text{EC} \times 10^3 \times \text{SP} / 100$$

where, SP is saturation percentage which is the percentage of water retained at the saturation point.

14b.1.2 Solubridge

The electrical conductivity of a soil is measured with the help of a conductivity meter also known as 'Solubridge' (or salt bridge) in which alternating current is employed. The balance point is indicated by a 'magic eye'. The conductivity cell attached with it consists of two equal sized platinum electrodes in the form of rectangular pieces fused parallel together on glass and covered with black spongy platinum on one side facing each other. Two wire leads connect it to proper terminals on the solubridge. A value known as cell constant is marked on the cell. Electrical conductivity is expressed in mhos/cm (reciprocal of resistance in ohms also as S i.e. Siemens). As most soil solutions have a conductivity much less than 0.1 mho therefore, the unit of measurement is expressed in terms of millimhos/cm (mmhos/cm) or mS/cm or milli Siemens/cm by multiplying with a factor of 10^3 .

14b.2 Precautions :

- Allow the soil suspension to stand for sufficient time to obtain a clear supernatant liquid.
- Dip the electrodes of the conductivity cell completely in the test solution to obtain an accurate reading or in conductivity bridges with pipette type conductivity cells which suck the extracts fully into the bulb of the pipette.

- Keep the electrodes dipped in distilled water when not in use.
- Set the temperature knob at the correct suspension temperature.

14b.3 Materials required :

- i. Balance
- ii. Beaker
- iii. Measuring cylinder
- iv. Solubridge with conductivity cell
- v. Ordinary filter paper
- vi. Wash bottle (with distilled water)
- vii. Thermometer

14b.4 Procedure :

- Weigh 20 g soil and transfer it into a 150 ml beaker. Add to it 40 ml of distilled water.
- Keep the suspension with intermittent stirring (10-15 min.) and leave aside for one hour in order to obtain a clear supernatant solution.
- Connect the solubridge with conductivity cell to power supply.
- Measure temperature of the suspension with the thermometer.
- Switch on the solubridge and adjust to temperature with the help of temperature knob.
- Dip the conductivity cell in the supernatant soil-water suspension or fill in the conductivity cell with the clear suspension.
- Then move the pointer of the dial so as to get the maximum area under the shade in the magic eye.
- Note the reading on the solubridge scale.

14b.5 Observations :

The pupil should take the following observations and calculate the electrical conductivity.

$$\begin{array}{l} \text{Cell constant} \\ \text{of the conductivity} \\ \text{cell as given} \\ \text{on the instrument} \end{array} \times \begin{array}{l} \text{Reading} \\ \text{of the} \\ \text{solubridge} \end{array} = Y \text{ mmhos/cm}$$

14b.6 Interpretation :

EC in mmhos/cm	Nature of soil
< 0.8	Normal for all crops
0.8—1.6	Critical for salt sensitive crops
1.6—2.5	Critical for salt tolerant crops
> 2.5	Injurious to all crops

14.3 Expected behavioural outcomes :

The pupil will be able to :

- estimate the total salts by evaporation techniques;
- operate the conductivity bridge;
- convert the EC values of soil-water extract into percent salt content of soils;
- Interpret the results.

Grade

The teacher should evaluate the pupil for the above abilities.

14.4 Questions :

- What steps are followed in determining total water soluble salts of soils by evaporation method?
- Why should H_2O_2 be used in the evaporation method?
- What do you understand by the term electrical conductivity?
- Why is the estimation of electrical conductivity in soils so important?
- What is the difference between mhos/cm, mmhos/cm and micro mhos/cm?
- What is the effect of dilution on electrical conductivity?
- How is electrical conductivity value of soil-water extract converted to per cent salt content of soil?
- Which instrument is used for determining electrical conductivity (EC) of soils?
- Give the principle of determination of EC of soils using the above instrument?
- What are the values of electrical conductivity of soils for normal, salt sensitive and salt tolerant crops?
- What precautions are necessary while determining EC of soil suspension?
- What is the effect of temperature on the EC of soils?

15. Activity Unit

DETERMINATION OF CARBONATES AND BICARBONATES IN THE SATURATED EXTRACT OF SOIL

15.1. Instructional objectives :

The pupil should be able to :

- explain the importance of carbonate ($\text{CO}_3^{=}$) and bicarbonate (HCO_3^-) ions as important components of total solids in soil-water extract;
- determine $\text{CO}_3^{=}$ and HCO_3^- in soil-water extract;
- explain the effect of high levels of $\text{CO}_3^{=}$ and HCO_3^- on soil properties.

15.2 Relevant information :

15.2.1 Composition of soil solution

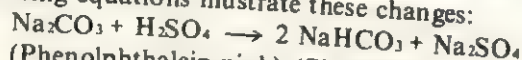
The soluble cations and anions commonly present in soils are Ca^{++} , Mg^{++} , K^+ , Na^+ , $\text{CO}_3^{=}$, HCO_3^- , $\text{SO}_4^{=}$ and Cl^- . The soil solution also contains $\text{PO}_4^{=}$, NO_3^- and traces of other anions and cations. In doing complete analysis, a determination of all these may be necessary if the sum of cations expressed on an equivalent basis significantly exceeds or falls short of the total anions estimated.

In waters containing high concentration of carbonate ions, there is a tendency for calcium and magnesium to precipitate as carbonates. This reaction reduces the concentrations of calcium and magnesium and increases the relative proportion of sodium leading to the alkalisation of the soil.

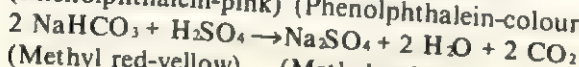
15.2.2 Principle .

Carbonate and bicarbonate in soil-water extract can be estimated by titrating the extract against standard acid using phenolphthalein and methyl red, respectively, as indicators. When

the pink colour of phenolphthalein disappears, it indicates one half of the neutralization of carbonate resulting in the formation of bicarbonate. At this stage methyl red indicator is added and the titration continued. When the colour changes from yellow to rose red, it indicates complete neutralization of bicarbonate. The following equations illustrate these changes:



(Phenolphthalein-pink) (Phenolphthalein-colour less)



(Methyl red-yellow) (Methyl red-rose red).

15.3 Precautions :

- Use freshly prepared or boiled and cooled distilled water for all purposes.
- Watch for the disappearance of the phenolphthalein pink colour very carefully.

15.4 Materials required :

- i. Conical flask
- ii. Burette
- iii. Glass rod
- iv. Phenolphthalein indicator
- v. Methyl red indicator
- vi. 0.1 N Sulphuric acid/Hydrochloric acid ($\text{H}_2\text{SO}_4/\text{HCl}$)
- vii. Spatula
- viii. Porcelain dish
- ix. Buchner (or suction) funnel
- x. Filter paper
- xi. Suction pump
- xii. Filter flask

15.5 Procedure :

- Prepare the saturation extract of soil as given below :

Take 200 g of soil in a porcelain dish and add distilled water in small quantities and mix intimately with a spatula every time and later add water drop by drop till the soil attains saturation. This can be judged by cutting the saturated soil in two equal halves. If, within a short time these two halves join together, then it can be said that the soil has attained saturation. Care should be taken that there is no free flowing

water on the surface of the soil. Transfer the above to a Buchner funnel fitted with filter paper and extract the soil-water using a suction pump. The extract so obtained is called soil water extract/saturation extract. The volume of the extract is measured and then diluted to 200 ml. This extract can be used for the determination of pH, EC and other cations and anions.

- Take 50 ml of the diluted extract and add 5 drops of phenolphthalein. Appearance of pink colour indicates the presence of carbonate.
- If carbonate is present, titrate with 0.1 N sulphuric acid/hydrochloric acid till the solution becomes colourless.
- Record this reading.
- Add a few drops of methyl red indicator and titrate with standard acid till the colour changes from yellow to rose red.
- Record this reading also.
- Repeat both the titrations a number of times so as to get two sets of concordant readings.

15.6 Observations and Calculations :

The pupil should record their observations in the following table and calculate the quantity of carbonates and bicarbonates by using two concordant readings of the standard acid used in titration.

Sl.	Volume of soil-water extract used	Volume of 0.1 N acid used with phenolphthalein	Volume of 0.1 N acid used with methyl red
1.			
2.			
3.			
4.			

- i. Volume of 0.1 N acid used with phenolphthalein = Z_1 ml
- ii. Volume of 0.1 N acid used with methyl red = Z_2 ml

Carbonates

50 ml of soil water extract = 2 x Z_1 ml of 0.1N acid

$$V_1 \times N_1 = V_2 \times N_2$$

$$50 \times N_1 = 2 Z_1 \times 0.1$$

$$N_1 = 2 Z_1 \times 0.1 / 50$$

Hence amount of CO_3^{2-} = Eq. wt. \times normality
 $= 30 \times 2 Z_1 \times 0.1 / 50$ g/litre

$$\begin{aligned}
 &= 30 \times 2 Z_1 \times 0.1 / 50 \times 5 \text{ g/200 ml} \\
 \% \text{ CO}_3^{--} \text{ in soil} &= 30 \times 2 Z_1 \times 0.1 / 250 \times 100/200 \\
 \% \text{ Na}_2\text{CO}_3 \text{ in soil} &= 53 \times 2 Z_1 \times 0.1 / 250 \times 100/200 \\
 \text{milliequivalents of CO}_3^{--} \text{ in 50 ml extract} &= 2 Z_1 \times 0.1 \\
 &\quad (200 \text{ g soil}) \\
 \text{milliequivalents of CO}_3^{--} \text{ in 100 g soil} &= 2 \times Z_1 \times 0.1 \times 100 / 200
 \end{aligned}$$

Bicarbonates

$$\begin{aligned}
 \text{Volume of 0.1N acid required for HCO}_3^- \text{ titration} &= Z_2 - Z_1 \text{ ml} \\
 50 \text{ ml of soil solution} &= (Z_2 - Z_1) \text{ ml of 0.1N H}_2\text{SO}_4 \\
 V_1 \times N_1 &= V_2 \times N_2 \\
 50 \times N_1 &= (Z_2 - Z_1) \times 0.1 \\
 N_1 &= (Z_2 - Z_1) \times 0.1 / 50 \\
 \text{Hence amount of HCO}_3^- &= \text{Eq. wt.} \times \text{normality} \\
 &= 61 \times (Z_2 - Z_1) \times 0.1 / 50 \text{ g/ litre} \\
 &= 61 \times (Z_2 - Z_1) \times 0.1 / 50 \times 5 \text{ g/200 ml} \\
 \% \text{ HCO}_3 \text{ in soil} &= 61 \times (Z_2 - Z_1) \times 0.1 / 250 \times 100 / 200 \\
 \text{m.e. of HCO}_3 \text{ in 50 ml extract} &= (Z_2 - Z_1) \times 0.1 \\
 &\quad (200 \text{ gram soil}) \\
 \text{m.e. of HCO}_3 \text{ in 100 g soil} &= (Z_2 - Z_1) \times 0.1 \times 100 / 200
 \end{aligned}$$

$$\begin{aligned}
 \text{Note : 1 ml of 0.1 N H}_2\text{SO}_4 \text{ HCl} &= 0.0053 \text{ g Na}_2\text{CO}_3 \\
 &= 0.003 \text{ g CO}_3^{--} \\
 &= 0.0061 \text{ g HCO}_3 \\
 &= 0.0084 \text{ g Na HCO}_3 \\
 1 \text{ ml of 0.1N H}_2\text{SO}_4 &= 0.1 \text{ milliequivalent of the ion}
 \end{aligned}$$

To express the amount of carbonate or bicarbonate in milliequivalents per 100 g of soil, multiply the amount of acid required to neutralize the carbonate or bicarbonate extracted from 100 g of soil with the normality of the solution. Methyl red gives sharper end point in the presence of sulphuric acid hydrochloric acid and should be preferred over methyl orange.

15.7 Interpretation:

Tentative criteria for evaluating whether carbonates or bicarbonates are in "satisfactory" or "high" range are given in the following table.

Tentative criteria for evaluating significance of CO_3^{2-} and HCO_3^- content found in water extract of soil

<i>Constituent</i>	<i>Method and basis of expressing result in soil</i>	<i>Usual range encountered</i>	<i>Satisfactory range for most plants</i>	<i>High range</i>
Carbonate	In saturation extract, m.e./litre	Trace to 1.0	Less than 0.1	More than 0.1
Bicarbonate	In saturation extract m.e./litre	Less than 1.0 to 5.0	0.10 to 2.5	More than 5.0
	In 1:5 soil water extract, expressed in ppm dry soil	50 to 250	Less than 100	More than 150

15.8 Expected behavioural outcomes :

The pupil will be able to :

- prepare the saturation extract of soil;
- explain the principle of determination of carbonate and bicarbonate in the same extract;
- titrate accurately;
- interpret the results.

Grade

The teacher should evaluate the pupil for the above abilities.

15.9 Questions :

- i. Why a saturation extract is prepared?
- ii. What is soil solution?
- iii. Why is phenolphthalein used in the determination of carbonate?
- iv. Why in the titration with phenolphthalein as indicator only half of the carbonate is considered?
- v. Why methyl red is used in determination of bicarbonates?
- vi. What is residual sodium carbonate?
- vii. How the cation composition in soil solution changes in the presence of high concentration of bicarbonate ion?
- viii. What will be the effect of dilution on these constituents?
- ix. Why freshly distilled water or freshly boiled and cooled distilled water is used in the estimation of carbonate and bicarbonate?

16. Activity Unit

DETERMINATION OF CHLORIDE IN SATURATED EXTRACT OF SOIL

16.1 Instructional objectives :

The pupil should be able to :

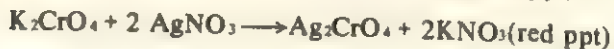
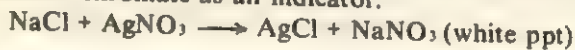
- explain the principle of chloride determination by titration;
- estimate the chloride content in soil-water extract;
- interpret chloride content in terms of its concentration in soil.

16.2 Relevant information :

Chloride is universally present in soil (mostly as soluble anion) and its content usually varies from 10 to 350 ppm. Specific toxicity of excess of chlorides on some crops has been observed.

16.2.1 Principle

Chloride in water-extract of soil can be determined by titrating the neutral extract against standard silver nitrate solution using potassium chromate as an indicator.



Silver chloride, being more insoluble than silver chromate, is precipitated first. When a solution of silver nitrate is added to a mixture of chloride and chromate ions, silver chloride separates out of the solution as white precipitate, thereby gradually reducing the chloride ion concentration in the mixture. When all such chloride ions are removed, a slight excess of the silver nitrate solution produces silver chromate (brick red colour) indicating the end point. Ag_2CrO_4 is not stable in presence of acid. Slightly acidic solutions can, however be neutralized with pure NaHCO_3 before titration.

16.3. Precautions :

- Prepare reagents in distilled water.
- Keep silver nitrate solution in dark coloured bottles away from sunlight.
- Take care against staining of clothes with silver nitrate.

16.4 Materials required :

- i. Porcelain dish
- ii. Pipette
- iii. Burette
- iv. Glass rod
- v. Silver nitrate solution (Dissolve 3.4 g of dry extra pure silver nitrate crystals in one litre of distilled water): equivalent to 0.02 N. The actual strength can be checked by titrating with 0.02N NaCl.
- vi. Potassium chromate solution (prepare 10% solution by dissolving 10 g of pure potassium chromate, free from chloride, in 100 ml of distilled water).

16.5 Procedure :

- In a clean porcelain dish take 50 ml of the soil-water extract (The soil-water extract which has already been titrated for carbonate and bicarbonate can also be used provided that the titration had not been carried out with standard hydrochloric acid).
- To this add one ml of K_2CrO_4 indicator solution.
- Run down silver nitrate solution slowly from the burette to the contents of the dish with constant stirring, until a faint, but permanent red colour is just imparted to the liquid.
- Take three concordant readings.

16.6 Observations and Calculations :

The pupil should calculate the chloride content on the basis of the three concordant readings.

Volume of 0.02N $AgNO_3$ used for 50 ml extract = A ml or
50 ml of soil extract = A ml of 0.02N $AgNO_3$

since, $V_1N_1 = V_2N_2$

$$50 \times N_1 = A \times 0.02$$

$$N_1 = A \times 0.02 / 50$$

Hence amount of Cl ions = Eq. wt \times normality
 Amount of Cl ions = $35.5 \times A \times 0.02 / 50$ g/litre
 = $35.5 \times A \times 0.02 / 50 \times 5$ g, 200 ml

16.7 Interpretation :

Tentative criteria for evaluating whether chloride content is in the "satisfactory" or "high to excess" range is given below:

Tentative criteria for evaluating significance of chloride ions found in water extract of soil

<i>Constituent</i>	<i>Method and basis of expressing result in soil</i>	<i>Usual range encountered</i>	<i>Satisfactory range for most plants</i>	<i>High to excess range</i>
Chloride	In saturation extract, in m.e./litre	Less than 0.1 to 5.0	Less than 5.0	More than 10
	In 1 : 5 soil-water extract expressed in ppm dry soil	Less than 10 to 350	Less than 75	More than 100

16.8 Expected behavioural outcomes :

The pupil will be able to :

- explain the principle of chloride estimation;
- titrate accurately;
- interpret the chloride content in terms of low and high.

Grade

The teacher should evaluate the pupil for the above abilities.

16.9 Questions :

- i. Why is the chloride content determination in soil-water extract necessary?
- ii. How does potassium chromate indicator act in the above estimation?
- iii. Can you use tap water for preparing silver nitrate solution? If not, why?
- iv. Why silver nitrate solution should be stored in dark coloured bottles?

- v. Explain why soil water extract should be in neutral pH range when using K_2CrO_4 ? In case it is acidic how will you proceed with the titration?
- vi. What is the range of chloride content of a normal soil?
- vii. Why is higher strength (say 0.1 N) of silver nitrate is not recommended for the determination of chloride?

17. Activity Unit

DETERMINATION OF ORGANIC CARBON IN SOILS

17.1 Instructional objectives :

The pupils should be able to :

- prepare the needed reagents;
- recall the chemical reactions occurring during determination;
- determine organic carbon in soils;
- estimate soil organic matter from organic carbon using Bemmlen factor;
- interpret the value of organic carbon for productivity rating of soil;
- estimate the nitrogen content in soils approximately.

17.2 Relevant information :

17.2.1 *What is organic matter ?*

All plant, animal and microbial residues both decomposed and undecomposed in the soil constitute the organic matter, most of which is of plant origin.

17.2.2 *What is Bemmlen factor ?*

Since organic matter, on an average, contains 58% carbon, the per cent organic matter can be obtained by multiplying the per cent organic carbon with $100/58$ or 1.724 which is known as Bemmlen factor.

17.2.3 *Importance of organic matter .*

Organic matter is an index of the productivity of the soil since it is a store-house of essential nutrients for plant growth. It is also a source of cation exchange capacity besides promoting desirable soil structure and influencing moisture retention and aeration of soils. Organic matter added to the soil does not remain stable but it breaks

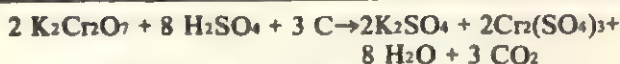
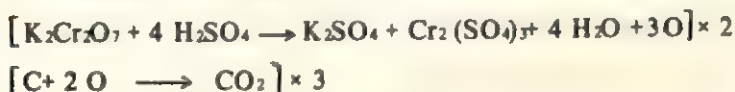
down (decomposes) due to the action of soil microorganisms. The ultimate products of the breakdown are water, carbon dioxide, free nitrogen, ammonia, methane gas, etc. Humus is another important product of microbial decomposition which remains in the soil and is somewhat stable. It is colloidal in nature and has some of the physicochemical properties as clay particles. Humus can absorb considerable amount of moisture and thus, adds to the water holding capacity of the soil. It has much higher cation exchange capacity than clay. The amount of soil nitrogen is almost in direct proportion to the amount of humus in the soil.

17.2.4 Principle

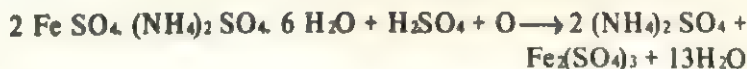
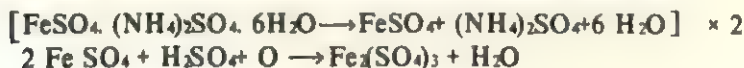
As per procedure given by Walkley and Black, the soil is digested with chromic and sulphuric acid making use of the heat of dilution of strong sulphuric acid so as to oxidise the humus. The excess of chromic acid, not reduced by soil organic matter, is determined by titration with standard ferrous ammonium sulphate solution in presence of, phosphoric acid, sodium fluoride and diphenylamine solution as indicator. At the end point, colour of suspension changes from violet, through blue to bright green. H_3PO_4 and NaF make the colour change distinct because of their suppression of the Fe^{+++} (ferric) ion activity which is generated during the titration with ferrous salt.

17.2.5 What reactions take place during determination of organic carbon?

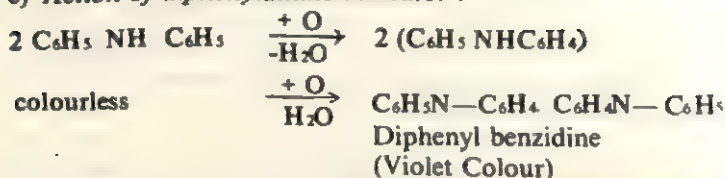
a) Oxidation of organic carbon



b) Titration of excess nascent oxygen (liberated by dichromate + sulphuric acid) with ferrous ammonium sulphate solution



c) *Action of diphenylamine indicator :*



At the end point diphenylamine becomes colourless and the background green colour is one to ferrous salts.

17.2.6 *Relationship between Carbon and Nitrogen :*

In arable mineral soil organic carbon and nitrogen are generally present in the ratio of 9-12: 1. This gives an idea of the relationship between carbon and nitrogen present in the soil. Through the determination of carbon, one can approximately obtain nitrogen content of the soil by dividing the value of organic carbon by the C/N ratio or on an average by 10.

17.3 *Precautions :*

- Use clean and dry apparatus.
- Prepare fresh solution of ferrous ammonium sulphate after some time.
- Prepare all reagents in distilled water.
- Handle strong sulphuric acid with caution.
- Carefully watch the changes in colour during the course of titration from violet to brilliant green through turbid blue

17.4 *Materials required:*

- i. 500 ml conical flask
- ii. pipette
- iii. Burette
- iv. 0.2 mm sieve
- v. 1 N $\text{K}_2\text{Cr}_2\text{O}_7$ solution (Dissolve 49 g of pure crystalline $\text{K}_2\text{Cr}_2\text{O}_7$ and make up to one litre with distilled water)
- vi. 0.5 N $\text{Fe} (\text{NH}_4)_2 (\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ (Mohr's salt) Dissolve 392.0 g of ferrous ammonium sulphate crystals in distilled water. Add 15 ml H_2SO_4 and make the volume to 2 litres with distilled water.
- vii. Diphenylamine indicator—Dissolve 0.5 g of diphenylamine in a mixture of 100 ml of conc. H_2SO_4 (nitrate free) and 20 ml distilled water.

- viii. Concentrated sulphuric acid (36 N)
- ix. Sodium fluoride powder
- x. Phosphoric acid (85%).

17.5 Procedure:

- Weigh accurately 2.0 g of soil sample (ground and passed through 0.2 mm Sieve) and transfer it in a dry 500 ml conical flask.
- Add 10 ml of 1N $K_2Cr_2O_7$ solution and shake it well to mix.
- Keep the conical flask on an asbestos sheet.
Add 20 ml conc. H_2SO_4 carefully from the side of flask, swirl the flask during addition.
- Keep the flask for 30 minutes to complete the reaction.
- Add 2 g of sodium fluoride and 10 ml phosphoric acid (orthophosphoric acid), 100 ml of distilled water and shake vigorously to mix.
- Now add 10 drops of the diphenylamine indicator (it will give violet colour to the suspension).
- Titrate the contents of the flask with N/2 ferrous ammonium sulphate solution with continuous shaking till the colour changes from violet to bright green.
- Note the volume of the ferrous ammonium sulphate solution used.
- Carry out a blank titration exactly in a similar way but without using soil.

17.6 Observations and Calculations:

The pupil should note down the reading, weight of soil and calculate the amount of organic carbon and organic matter present in the soil.

Weight of the soil taken = S g

Amount of N/2 Ferrous ammonium sulphate solution used for the blank titration = A ml

Volume of N/2 ferrous ammonium sulphate solution used for titrating the excess 1N $K_2Cr_2O_7$ = B ml

Volume of 1N $K_2Cr_2O_7$ used for the oxidation of carbon = $(A-B)/2$ ml

(1 ml of 1N $K_2Cr_2O_7$ = 0.003 g organic carbon)

per cent organic carbon in the soil $(A-B)/2 \times 0.003 \times 100/S = Z$

per cent organic matter = $Z \times 1.724$

17.7 Interpretation:

Per cent organic carbon in soil
below 0.50
0.50—0.75
above 0.75

Rating
low
medium
high

17.8 Expected behavioural outcomes:

The pupil will be able to :

- explain the oxidation and reduction reactions;
- comprehend the chemical reactions taking place after addition of various reagents;
- prepare reagents and perform the titration;
- interpret the value of organic carbon for estimation of nitrogen and productivity rating of the soil.

Grade

The teacher should evaluate the pupil for the above abilities.

17.9 Questions :

- i. What is the function of $K_2Cr_2O_7$ in the estimation of organic carbon?
- ii. Why do we use concentrated H_2SO_4 in conjunction with $K_2Cr_2O_7$?
- iii. Why do you need sodium fluoride and phosphoric acid?
- iv. What is diphenylamine? Why is it used in the determination of organic carbon in the soil?
- v. What is Mohr's salt? Why H_2SO_4 is added in preparing the 0.5 N solution of Mohr's salt?
- vi. What is the actual substance that is being titrated while titrating with Mohr's salt solution?
- vii. Why is the concentration of $Fe(NH_4)_2(SO_4)_2$ kept lower than that of $K_2Cr_2O_7$?
- viii. To get per cent organic matter, per cent organic carbon is multiplied by 1.724, why?
- ix. Why is organic matter content of soils an index for nitrogen availability in soils?
- x. What are the functions of organic matter in the soil?
- xi. What is a blank titration? What for it is run?

18. Activity Unit

DETERMINATION OF AVAILABLE NITROGEN IN SOIL

18.1 Instructional objectives:

The pupil should be able to:

- recall the forms of available nitrogen;
- determine available nitrogen;
- interpret the nitrogen value in terms of soil fertility.

18.2 Relevant information:

18.2.1 *Forms of nitrogen and their availability to plants*

Nitrogen is generally taken up by plants as nitrate under aerobic conditions. Under anaerobic or flooded situations when oxygen is in short supply certain plants like rice can take up as ammonium ions. The sum of ammonical and nitrate forms of nitrogen is much smaller than the total quantity of soil nitrogen most of which is in complex organic form (proteins, amino acids, etc.) in the humus fraction and becomes slowly available to the plants during their growth. Since the bulk of total nitrogen is present in the organic complex a method that takes this potential reserve source into account, can be used for assessing the nitrogen supplying capacity of a soil. One such a procedure is the alkaline potassium permanganate method (Subbiah and Asija, 1956) which is described below.

18.2.2 *Principle*

Alkaline KMnO_4 is a mild oxidizing agent and can extract out the easily hydrolysable and oxidizable fractions of organic nitrogen. A known weight of the soil is treated with a measured quantity of alkaline KMnO_4 solution and subjected to boiling; the ammonia that is evolved, is absorbed in a known volume of a standard acid, the

excess of which is back titrated with a standard alkali, using methyl red indicator.

18.3 Precautions :

- Dip the delivery end in the receiver containing the standard acid before adding NaOH solution in the distillation flask.
- Close the mouth of Kjeldahl flask immediately after the addition of NaOH so as to avoid any loss of NH_3 .
- Add the indicator before starting distillation to ensure that the receiver contains sufficient standard acid.
- Keep all connections air tight to avoid loss of NH_3 .
- Avoid back suction by removing the delivery end from the receiver before stopping the burner/heater.
- Collect only 100 ml of the distillate during 30 minutes boiling at a steady rate.

18.4 Materials required :

- i. Kjeldahl flask (800 ml) and distillation assembly,
- ii. Measuring cylinder
- iii. Pipette
- iv. Burette
- v. Conical flask
- vi. 0.32% KMnO_4 —Dissolve 3.2 g KMnO_4 in distilled water and make up the volume to one litre.
- vii. 2.5% NaOH—Dissolve 25 g sodium hydroxide (pellets) in distilled water and make up the volume to one litre.
- viii. Methyl red indicator (0.15 per cent)—Dissolve 0.15 g of methyl red powder in 50 ml ethyl alcohol and make up the final volume to 100 ml with water.
- ix. 0.02 N NaOH—Dissolve 0.8 g of NaOH in one litre of water and standardise with standard acid using methyl red indicator.
- x. 0.02 N H_2SO_4 —Take one ml of 36 N H_2SO_4 (sp. gr. 1.84) and dissolve in 1800 ml of distilled water; standardise with standard alkali and adjust the strength to 0.02 N.

18.5 Procedure :

- Transfer 20 g sample of soil carefully into Kjeldahl distillation flask.
- Moisten the sample with distilled water and fix the Kjeldahl

assembly.

- Add 100 ml of 0.32% KMnO_4 solution and 100 ml of 2.5% NaOH solution and immediately fit the stopper.
- Take 25 ml of 0.02 N H_2SO_4 in 150 ml conical flask. Add 3-4 drops of methyl red and dip the end of the delivery tube in it.
- Distil ammonia by steadily heating the distillation flask and collect about 100 ml of the distillate in 30 minutes time.
- Titrate the excess of standard sulphuric acid in the conical flask with 0.02 N NaOH and note the volume used.

18.6 Observation and calculations :

The pupil should note the reading and calculate the available nitrogen content of the soil as below :

Weight of soil taken	= 20 g
Volume of 0.02 N H_2SO_4	= 25 ml
Volume of 0.02 N NaOH required for back titration	= X ml
Volume of 0.02N H_2SO_4 used by NH_3 evolved	= 25-X ml
1 ml of 0.02N H_2SO_4	= 0.00028 g of N
Percent available nitrogen	= $(25-X) \times 0.00028 \times 100/20$
Available nitrogen in ppm	= percentage $\times 10,000$
Available nitrogen in Kg/ ha	= percentage $\times 22400$

Note : For expressing available nitrogen in Kg/ha, assume 1 ha of furrow slice (0-15cm) of the soil weighs 2.24 million kg

18.7 Interpretation :

<i>Amount of available nitrogen (Kg/ha)</i>	<i>Rating</i>
Less than 272	Low
272—544	Medium
More than 544	High

18.8 Expected behavioural outcomes :

The pupil will be able to :

- differentiate between total and available nitrogen in soil;
- explain the methodology;
- conduct the analysis;

Grade

— interpret the results.

The teacher should evaluate the pupil for the above abilities.

18.9 Questions :

- i. What is meant by available nitrogen?
- ii. Name the various forms of nitrogen that occur in soil.
- iii. Which form or forms is/are important for crop growth?
- iv. What is the principle involved in estimating available nitrogen by alkaline permanganate method?
- v. How is the loss of ammonia prevented during analysis?
- vi. What is the effect of addition of alkaline permanganate on soil nitrogen?
- vii. Why a steady distillation rate and time be maintained for collection of the distillate in the receiver flask?
- viii. What will you do if the standard acid in the receiver turns yellow?
- ix. Why the total nitrogen content in the soil can not be used as the index of its availability to plants?
- x. How is it assumed that one hectare of the furrow slice (0-15cm) of field soil is equivalent to 2.24 million kg?

19. Activity Unit

DETERMINATION OF AVAILABLE PHOSPHORUS IN SOIL

19.1 Instructional objectives :

The pupil should be able to :

- recall the forms in which phosphorus is present in soil and is absorbed by plants;
- determine available phosphorus;
- interpret available phosphorus data with soil fertility level.

19.2 Relevant information :

19.2.1 What is available phosphorus?

Phosphorus occurs in the soil both in organic and inorganic combinations. Most of the total P in soil is in insoluble form and hence not easily available to plants. That fraction of total P which is susceptible to absorption by plant during their growth is known as available phosphorus. Plants take up phosphorus mostly as readily soluble H_2PO_4^- ions and some amount also as HPO_4^{2-} ions. There are several chemical extractants used for estimating plant available P and among them NaHCO_3 solution is one which is widely employed for predicting the phosphorus supplying power of soils.

19.2.3 Principle

A dilute solution of NaHCO_3 adjusted to pH 8.5 raises the carbonate activity in the soil and therefore, decreases the activity of calcium. Thus, some phosphorus from the surface of calcium phosphates is extracted due to its solubility in this reagent. This reagent also extracts some phosphorus from the surface of Al and Fe bound phosphates. Because of the alkaline nature of the sodium bicarbonate solution, some fraction of soil organic matter (humus) also gets solubilised and gives a dark colour to the extract. Hence,

Darco G-60 (a type of activated charcoal) is used to adsorb the dispersed organic matter and make the filtrate colourless. The soluble phosphate forms a complex with molybdate ions in acidic medium and this on reduction with stannous chloride gives a blue coloured solution. The intensity of colour which is proportional to the concentration of phosphate in the soil extract is read with the help of a photo-electric colorimeter at a wave length of $660\text{m}\mu$ (or nm) using a red filter. The concentration of phosphorus (in the soil extract) is found out from the standard curve prepared before the estimation.

19.2.3 Colorimetric analysis

Colorimetry is based on the principle that coloured solutions preferentially absorb radiation of certain wavelengths (of white light) and the colour observed is characteristic of the wavelengths not absorbed. The colour or the wavelength band of incident light used for colorimetric determination is selected to coincide with that most absorbed by the test solution and this is achieved by passage of the white light through the appropriate light filter. The magnitude of absorption is proportional to the intensity of the colour which in turn, is directly related to the concentration within certain limits.

19.3 Precautions :

- Check the Darco G-60 whether it contains any phosphorus extractable with the bicarbonate reagent.
- Filtrate must be colourless. If not add more Darco-G-60, shake and filter again.
- Handle the test tube from the top and wipe it clean with a piece of filter paper before putting in the sample holder.
- Prepare the dilute stannous chloride fresh after 2-4 hours.
- Record the colorimeter reading within 10-15 minutes after development of the colour.
- Ensure that the blank should be practically free from colour, that is there is no contamination of phosphorus.
- Do not use the two extremes of the standard curve for finding out the concentration of P in the test solution.

19.4 Materials required :

- i. Conical flask
- ii. End over end/horizontal shaker
- iii. Funnel

- iv. Whatman No. 1 filter paper
- v. Pipette
- vi. Volumetric flask
- vii. Photo-electric colorimeter (double or matched photocell type)
- viii. pH meter
- ix. 0.5M sodium bicarbonate extractant adjusted to pH 8.5—Dissolve 42 g of pure sodium bicarbonate in about 900 ml of distilled water and adjust the pH of the solution to 8.5 using a pH meter by adding either NaOH or HCl and make up to 1 litre.
- x. Approximately 10 N hydrochloric acid (Concentrated HCl is usually about 11.5 N)
- xi. Stannous chloride—(chemically pure)
- xii. Ammonium molybdate, powder—extra pure
- xiii. Activated charcoal (Darco G-60). Make it free from soluble phosphorus by repeated washings with the extractant *i.e.* the same bicarbonate solution and finally washing with distilled water. Test it to be free of P using the same procedure for the estimation of phosphorus. Absence of blue tinge after the addition of SnCl_2 reagent indicates the absence of P in Darco G-60.
- xiv. Chloromolybdic acid reagent (1.5%)—
Dissolve 15 g of ammonium molybdate (in powdered form) in 300 ml distilled water, warm to about 50°C . Add to the solution 410 ml of 10 N HCl gradually with constant stirring and dilute it to one litre with distilled water.
- xv. Potassium dihydrogen phosphate (KH_2PO_4)—extra pure
- xvi. Stannous chloride (stock solution)—
Dissolve 10 g of $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$ in 25 ml of conc. HCl. Warm if necessary. Add a piece of pure metallic tin and store the solution in a glass stoppered brown bottle. The solution will be stable for some time.
- xvii. Stannous chloride (working solution)
Dilute 1 ml of the stock solution of 66.0 ml with distilled water just before use.

19.5 Procedure :

- Weigh 2.5 g of soil and transfer to a 100 ml conical flask.
- Add a pinch of Darco G-60 and 50 ml of 0.5M sodium bicarbonate solution (pH 8.5).

- Mix and shake the flask on the electric shaker for half an hour and filter immediately through a dry filter paper.
- Reject first few ml of the filtrate.
- Prepare a blank solution in which all reagents are added except the soil.
- Take 5 ml of the filtrate in a 25 ml volumetric flask and add 5 ml of chloromolybdic acid reagent carefully avoiding frothing. Mix well slowly and carefully by shaking with hand until the liberation of CO_2 stops.
- Add about 10 ml of distilled water.
- Add 1 ml of the freshly diluted solution of stannous chloride reagent (working solution) and make up the volume up to the mark with distilled water.
- Insert the 660 mu wavelength filter in the colorimeter and switch it on. Let it warm for about 10-15 minutes.
- Adjust the pointer on the galvanometer to read zero transmittance.
- Rinse the colorimeter tube with blank solution and pour a suitable volume in it. Wipe the outside with filter or blotting paper. Place the tube in the cuvette well and make the pointer read 100 with the 100 set knob.
- Pour the test solution in the same tube after cleaning it and read the per cent transmittance or the absorbance.

— *Preparation of standard curve*

Prepare a standard solution of P by dissolving 0.439 g of potassium dihydrogen phosphate (KH_2PO_4) dried at 50°C in half a litre of distilled water. 25 ml of 7N H_2SO_4 (approx. 1:4) is added and volume made up to one litre with distilled water. (This stock solution contains 100 ppm P). From this stock solution (100 ppm P) pipette out 5 ml into a 250 ml volumetric flask and make up to mark with distilled water. This gives 5 ppm working solution. Now pipette out 1, 2, 3, 4 and 5 ml of this solution in 5 different 25 ml volumetric flasks along with the flask without this solution. Then proceed to develop colour in all the six flasks like the test sample and take the absorbance or transmission readings. Plot the standard curve of phosphorus concentration versus absorbance readings on a graph paper. The curve should be fairly linear in nature. If not, repeat this process again.

19.6 Observations and Calculations :

The pupil should take the readings and with the help of the standard curve find out the concentration of P and calculate the available P content in the soil.

Weight of soil sample taken	= 2.5 g
Volume of 0.5 N NaHCO_3 solution added	= 50 ml
Volume of filtrate taken	= 5 ml
Final volume after colour development (dilution = $20 \times 5 = 100$ times)	= 25 ml
Transmittance of the test solution	= T
Absorbance of the test solution	= A
Concentration of P read from the standard curve	= C ppm
ppm of available P	= $C \times 100$
kg of available P/ha	= ppm P $\times 2.24$

19.7 Interpretation :

<i>Amount of available P (Kg/ha) in soil</i>	<i>Rating</i>
below 11.2	Low
11.2—22.4	Medium
above 22.4	High

19.8 Expected behavioural outcomes :

The pupil will be able to :

- explain the principle of extraction of available phosphorus;
- explain the technique of colorimetric analysis;
- prepare the standard curve;
- determine available phosphorus;
- interpret the results for application of phosphatic fertilizer.

Grade

The teacher should evaluate the pupil for the above abilities.

19.9 Questions :

- What is meant by available phosphorus?
- In what forms available phosphorus is present in soils?
- What is the advantage of using NaHCO_3 solution of pH 8.5

for extraction of available P?

- iv. What is the function of Darco G-60?
- v. What is the use of chloromolybdic acid reagent in the determination of available phosphorus?
- vi. How does stannous chloride help in colour development? Can any other chemical be used instead?
- vii. Why should stannous chloride working solution be prepared a fresh?
- viii. At what wave length is the colour intensity measured in the estimation of available phosphorus and why?
- ix. What is the purpose of adding 7N sulphuric acid to the 100 ppm P stock solution of KH_2PO_4 ?
- x. What is the relationship between ppm and Kg/ha?
- xi. What are the limits of sufficiency and deficiency of available phosphorus in soils?
- xii. If phosphorus rating is low, what recommendations will you make for soils of the area?

20. Activity Unit

DETERMINATION OF AVAILABLE POTASSIUM IN SOIL

20.1 Instructional objectives :

The pupil should be able to :

- recall the forms of potassium in soils;
- explain the significance of available potassium to plant;
- determine available K in soil;
- interpret values of K in terms of soil fertility.

20.2 Relevant information :

20.2.1 Forms of Potassium

The forms of potassium in soils are :

- i) water soluble K;
- ii) exchangeable K;
- iii) slowly available (fixed) K; and
- iv) unavailable (lattice bound) K.

Available potassium in soils is generally the sum of water soluble and exchangeable K which can be readily taken by plants. As water soluble and exchangeable K are removed by cropping or lost in leaching, some of the reserve K (fixed and lattice bound) weather out from various potash bearing minerals like feldspars and micas and may become available during the crop growth.

20.2.2 Extractant used for the determination of available K

A solution of neutral (pH 7.0) normal (1N) ammonium acetate ($\text{CH}_3\text{COONH}_4$) is generally used for extracting both water soluble and exchangeable K.

20.2.3 Principle

Ammonium ions in ammonium acetate, replace exchangeable

K^+ ions held on the colloidal interfaces of the soil. Also, as NH_4^+ holds highly charged layers together just as K^+ , the release of non-exchangeable K^+ to exchangeable form is retarded during extraction. The ammonium ion provides a sharp and rapid separation from exchange complex while other cations bring about a gradual replacement of either lesser or greater amount of K^+ which generally increases with the period of contact. Hence ammonium is preferred.

The estimation of potassium is done with the help of a flame photometer. The flame photometer works on the principle that every element on excitation over a flame emits its characteristic radiations and gives specific colour (Na-yellow, K-violet) to the non-sooty flame. As the intensity of this particular radiation is proportional to the concentration the latter can be measured with this instrument after necessary calibration.

20.3 Precautions :

- See that the filtrate (extract) is perfectly clear.
- Maintain the air pressure in flame photometer within 0.4 to 0.6 kg/cm². Air pressure must not fluctuate during analyses. The gas for burning should come at a steady rate.
- Open the gas (acetylene or LPG) inlet after opening the air inlet and close it before shutting of the air supply.
- Keep the flame soot-free and pale blue.
- Allow the flame photometer to warm up for a period of 5 to 10 minutes before actual use.
- Ensure a steady zero reading with blank.

20.4 Materials required :

- i. Pipette
- ii. Conical flask
- iii. Flame photometer with K filter
- iv. Normal ammonium acetate (pH 7.0) —
Dissolve 77.10 g of solid ammonium acetate in distilled water and make up to one litre. Adjust to pH 7.0 by adding either NH_4OH or acetic acid.
- v. pH meter
- vi. Mechanical shaker
- vii. Funnel
- viii. Filter paper (Whatman No 1)
- ix. Standard potassium solution—Dissolve 1.91 g of extra pur KCl (dried at 60°C for 1 hr) in distilled water and make up

to one litre. It gives 1000 ppm stock solution of K. Dilute this stock solution 20 times before use so as to have 50 ppm K solution. (Prepare the stock solution at suitable intervals as quite often fungus growth is noticed on storage).

- x. From the 50 ppm standard K solution, prepare 5, 10, 20, 30, 40 ppm solutions for preparing the standard curve.

20.5 Procedure :

- Weigh 5 g soil in a dry conical flask (100-150 ml).
- Add to it 25 ml neutral normal ammonium acetate solution.
- Shake the contents of the flask on an electric shaker for 5 minutes and filter immediately through a dry filter paper (No.1) Reject first few ml of the filtrate.
- Feed the filtrate to the atomizer of the flame photometer after its scale (0-100) has already been adjusted to zero with blank and to 100 with 50 ppm standard solution of K. Note the reading.
- Locate this reading on the standard curve and calculate the amount of K in the soil.

Preparation of standard curve :

Adjust 100 of the galvanometer (attached to the flame photometer) with 50 ppm K solution. Then take readings by feeding solutions of different concentrations (5, 10, 20, 30, and 40 ppm K) and plot the curve showing relationship between concentrations of K^+ versus galvanometer readings.

20.6 Observations and Calculations :

The pupil should take the readings and calculate the amount of available potassium in the soil.

- | | | |
|---|---|------------------|
| — Weight of soil sample | = | 5 g |
| — Volume of neutral normal CH_3COONH_4 added | = | 25 ml |
| — Reading of the flame photometer for the test sample | = | A |
| — ppm as read from the standard curve | = | B |
| — ppm of available K in soil = $B \times \text{total dilution}$ | = | Z |
| | = | $B \times 5 = Z$ |
| Available K in kg/ha | = | $Z \times 2.24$ |

20.7 Interpretation :

Available K (kg/ha) in soils

Less than 120

120 - 280

More than 280

Rating

.. Low

.. Medium

.. High

20.8. Expected behavioural outcomes :

The pupil will be able to :

- explain the principle of extraction of available K with ammonium acetate;
- prepare the standard curve;
- operate the flame photometer;
- calculate the flame photometer;
- calculate and interpret the results.

Grades

The teacher should evaluate the pupil for the above abilities.

20.9 Questions :

- i. In what forms potassium is present in soil?
- ii. What is meant by available potassium and which forms contribute to this fraction?
- iii. Why is neutral ammonium acetate preferred over other salts for determining exchangeable K?
- iv. Why ammonium acetate of pH 7 alone is used as an extractant?
- v. How can you evaluate the potentially available (reserve) source of K in a soil?
- vi. What are the limits of sufficiency and deficiency of available potassium in soils?
- vii. Why the colourless flame of a gas burner turns yellow in contact with sodium salts?
- viii. On what principle the flame photometer operates?
- ix. What precautions should be taken while working with flame photometer and why?
- x. What other chemical methods could be used for estimation of available K ?
- xi. How can you actually demonstrate in the field that release of fixed K has taken place.

21. Activity Unit

DETERMINATION OF GYPSUM REQUIREMENT OF SOIL

21.1 Instructional objectives :

The pupil should be able to :

- explain the principle of reclamation of alkali (sodic) soils and determination of quantity of amendment requirement to be added;
- explain how gypsum application improves physical condition of the soil through reclamation.

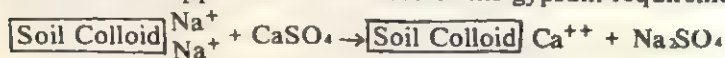
21.2 Relevant information :

21.2.1 *Why is gypsum added to soil?*

When the exchangeable sodium percentage (ESP) exceeds 15 (15% of the cation exchange capacity), deterioration of the soil physical properties sets in over and above the rise in pH. Exchangeable sodium percentage of soil is obtained by determining exchangeable sodium and cation exchange capacity (expressed as milliequivalent/ 100g) and using the relationship $ESP = \frac{\text{Exch. Na} \times 100}{\text{C.E.C.}}$. As ESP exceeds 15 colloidal particles get dispersed, organic matter dissolves, the soil turns too soft when wet and too hard when dry and becomes structureless. Aeration and drainage are impeded. Plant roots are damaged severely and die in alkaline environment. To improve physical conditions of such soils or to reclaim them, gypsum (calcium sulphate) is added so that Na^+ from exchange complex is replaced by Ca^{++} and the ESP is brought down to well below 15. The process of reclamation also involves flooding the soil so that the sodium sulphate (Na_2SO_4) formed is leached out.

To find out the economical amount of gypsum needed to reclaim and bring about favourable physical conditions of the soil for crop growth, the gypsum requirement (of the soil) is usually determined

according to Schoonover's method (1952). In this method, when an alkali (sodic) soil is shaken with a nearly saturated gypsum solution, Ca^{++} exchanges for Na^+ ion and consequent loss of Ca^{++} in the solution is an approximate measure of the gypsum requirement.



Calcium in the solution is determined by versenate (ethylene diamine tetra acetic acid, disodium sulphate i.e. EDTA) titration.

21.2.2 Principle

The method is based on the fact that Ca^{++} , Mg^{++} and a number of other polyvalent ions form stable complexes with versenate (EDTA disodium salt) at different pH. Sn^{++} , Cu^{++} , Zn^{++} , Fe^{++} and Mn^{++} interfere in the estimation of Ca^{++} and Mg^{++} if present in appreciable amounts. Their interference is minimised by the use of 2 per cent KCN or NaCN solution but normally this is not necessary.

A known volume of the aliquot is titrated with standard versenate (N/100) solution using murexide (ammonium purpurate) indicator in presence of excess of OH^- ions in alkaline solution. The end point is a change of colour from red to blue at pH above 10 when all the Ca^{++} present in solution form a complex with EDTA

21.3 Precautions :

- Determine gypsum requirement of high pH (8.5 and above) and high ESP soils only
- Use saturated gypsum solution.
- Handle the cyanide solution (deadly poisonous) if used, with extreme caution.
- Open the liquid ammonia bottle only after cooling to ice temperature.

21.4 Materials required :

- i. Conical flask
- ii. Pipette
- iii. Burette
- iv. Porcelain dish
- v. Mechanical shaker
- vi. Saturated gypsum solution—Shake 5 g pure $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ for an hour in one litre of water. Filter and determine calcium concentration by versenate titration method.

- vii. $\text{NH}_4\text{Cl}-\text{NH}_4\text{OH}$ buffer (pH 10.0)—Dissolve 67.5 g NH_4Cl in 570 ml strong NH_4OH (sp. gravity 0.88) and dilute to 1 litre. Check the pH, if necessary. Store at a cool place.
- viii. (Eriochrome black T indicator (solochrome black))—Dissolve 0.5 g of solid indicator with 4.5 g hydroxylamine hydrochloride in 100 ml of 95 per cent ethanol (rectified spirit)
- ix. 0.01N (N/100) EDTA—Dissolve 2g EDTA in 900 ml of water. Add 50 mg $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$. Mix both these thoroughly. Determine the normality of versenate solution by titrating it with standard calcium solution.
- x. Standard calcium (chloride) solution 0.01N (N/100) Dissolve exactly 0.5 g of extra pure calcium carbonate in 10 ml of approximately 3N HCl (1 part of conc. acid+3 parts of distilled water) and make up the volume to one litre.

21.5 Procedure :

- Weigh and add 5g of soil in a conical flask (150 ml) containing 100 ml of saturated gypsum solution.
- Stopper and shake for 5 minutes on a mechanical shaker and filter through a dry paper (Whatman No. 1).
- Reject the first few ml of the filtrate.
- Pipette out 5 ml of the clear filtrate into 100 ml porcelain dish or conical flask and dilute to 25 ml with distilled water.
- Add 1.0 ml of NH_4OH buffer.
- Add 3-4 drops of eriochrome black T indicator.
- Titrate with standard EDTA until colour changes from red to blue.
- Titrate similarly 5 ml of standard saturated gypsum solution separately as a blank (without soil).

21.6 Observations and Calculations :

The pupil should record information and readings and calculate the amount of gypsum required for reclamation of one hectare area of the field.

- Weight of the soil taken = 5 g
- Amount of filtrate taken = 5 ml
- Normality of EDTA used =
- Volume of EDTA used for blank titration taking 5 ml of saturated gypsum solution = X ml
- Volume of EDTA used for 5 ml of extract of test sample = Y ml

- Volume of EDTA used for a Ca adsorbed by soil colloids (equivalent to 5 ml extract) = $X - Y$ ml.
- Gypsum requirement (GR)
in tonnes/ha for plough layer = $848N(X - Y)$
where : X = Vol. of EDTA used for blank titration
 Y = Vol. of EDTA used for test sample
 N = Normality of EDTA used.

21.7 Expected behavioural outcomes :

The pupil will be able to :

- explain the adverse physico-chemical properties of alkali soils;
- explain the principle involved in the determination;
- interpret how gypsum requirement is related to ESP;
- comprehend the methodology and calculation of gypsum required.

Grade

The teacher should evaluate the pupil for the above abilities.

21.8 Questions :

- i. What is an alkali soil? How does it differ from a saline soil?
- ii. What is ESP and how is this found out?
- iii. How does excessive ESP affect the physical properties of soil?
- iv. Why an alkali soil when dry appear black/dark coloured at the surface?
- v. What reaction takes place when an alkali soil and what are the changes that take place in ESP values?
- vi. Why saturated solution of gypsum be used?
- vii. Name the method of determination of gypsum requirement of soil?
- viii. Name the metals which interfere in the estimation of Ca and Mg using EDTA titration. How is their interference avoided?
- ix. What is EDTA?
- x. Name the indicators and buffers used in the above estimation.
- xi. How does the indicator work?

- xii. Why is a blank titration run separately?
- xiii. What are the steps involved in calculating the gypsum requirement in t/ha for 30 cm soil depth?

22. Activity Unit

DETERMINATION OF LIME REQUIREMENT OF SOIL

22.1 Instructional objectives :

The pupil should be able to :

- recall the properties of acid soil;
- explain how liming can improve such soils;
- determine lime requirement of soils;
- link pH of the soil with lime requirement.

22.2 Relevant information :

22.2.1 What is lime requirement (LR)?

It is defined as the amount of lime needed to bring the pH value of the soil from its present level to a desired pH value. Obviously, the determination is confined to acid soils only. The growth of most crops suffer adversely if the soils are excessively acidic in nature.

22.2.2 Sources which induce acidity in soils

Acidity in soils could be induced from several sources namely, humus or organic matter, aluminosilicate clays, hydrous oxides of iron and aluminium, soluble salts, carbon dioxide, acid producing minerals, fertilizers, etc.

Soil organic matter or humus contains reactive carboxylic and phenolic groups which are capable of bonding H^+ ions. Such H^+ ions will exhibit their activity in soil water depending on the dissociation constant of organic acids formed.

22.2.3 How is acidity developed?

It has been shown that the total charge on soil clays falls into two categories, one is called permanent (negative) charge which is responsible for electrostatic bonding of H^+ , Al^{3+} and other cations. This charge results from isomorphous substitution (Substitution of a

lower valency cation like Al^{3+} or Mg^{2+} in the clay lattice in place of a higher valency one like Si^{4+} or Al^{3+}). The other is the pH dependent charge and results in the covalent bonding of hydrogen and other ions, arising due to carboxylic and phenolic groups of soil humus. The pH dependent charge also originates on soil clays from structural OH groups at corners and edges of the clay lattice which may dissociate H^+ ions. Amorphous hydroxy compounds of Al and Fe may also coat the aluminosilicate clays and at higher pH values they may hydrolyse and unblock exchange sites on the minerals. It is believed that both Al^{3+} and H^+ , along with loss of basic cations such as Ca^{++} , Mg^{++} and K^+ , are involved in the development of acid soils. Fertilizers giving rise to excessive acids (like ammonium sulphate) also produce soil acidity on prolonged use.

22.2.4 How is soil acidity corrected?

Soil acidity is corrected by the use of liming materials. There are many agricultural liming materials like calcium oxide, calcium hydroxide, calcium carbonate, lime-stone, dolomite, lime sludge, etc.

22.2.5 Principle

A number of laboratory methods are available for determination of lime requirement of soil. The method developed by Shoemaker and associates (1961) which is followed quite widely is based on the depression in pH of a buffered solution when an acid soil is added to it. Lime requirement of a soil is proportional to the depression in the pH of the buffer and can be seen from the table given under the heading "procedure".

For soils having pH 6.4 or above, no lime is necessary and when the pH is 6.3 or well below it, liming is to be recommended more particularly for crops which are sensitive to soil acidity.

22.3 Precautions :

- Do not allow the electrode of the pH meter to remain in the test solution or soil suspension any longer than necessary.
- Carefully follow the precautions given under Sub Unit 13b.
- Check and adjust the pH of the buffer correctly.

22.4 Materials required :

- i. Glass electrode pH meter
- ii. Pipette

iii. Beaker

iv. Extractant buffer solution—Dissolve 1.8 g of para-nitrophenol, 2.0 g of $\text{Ca}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$ (calcium acetate), 2.5 ml triethanol-amine, 3.0 g potassium chromate, and 53 g $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ (calcium chloride), all chemically pure, in approximately 800 ml of distilled water. Adjust the pH of this buffer to 7.5, using dilute hydrochloric acid or sodium hydroxide solutions and dilute to one litre. Check the pH again.

22.5 Procedure :

- Weigh 5g of soil sample in a dry 50 ml beaker and to this add 5 ml distilled water and 10 ml of extractant buffer.
- Shake continuously for 10 minutes or intermittently for 20 minutes and read the pH of soil buffer suspension immediately with the pH meter (as in Sub Unit 13 b)
- Use table below (as given by Shoemaker) to find out the lime requirement. The values are given in tonnes of pure CaCO_3 per hectare required to bring the soil to pH indicated.

Lime required to bring soil to an indicated pH level
(Tonnes per hectare of pure CaCO_3)

<i>pH of soil- buffer suspension -</i>	<i>pH 6.0</i>	<i>pH 6.4</i>	<i>pH 6.8</i>
6.7	2.47	2.96	3.46
6.6	3.46	4.20	4.69
6.5	4.45	5.43	6.17
6.4	5.68	6.67	7.66
6.3	6.67	7.90	9.14
6.2	7.66	9.14	10.37
6.1	8.64	10.37	11.36
6.0	9.63	11.61	13.34
5.9	10.87	12.84	14.82
5.8	11.86	14.08	16.05
5.7	12.34	15.31	17.64
5.6	13.83	16.54	19.02
5.5	14.82	17.78	20.50
5.4	16.05	19.02	21.98
5.3	17.04	20.25	23.22
5.1	19.27	22.48	26.18
5.0	20.25	23.71	27.66
4.9	21.24	24.95	29.15
4.8	22.48	26.18	30.63

22.6 Observations and Calculations:

The pupil should record the pH reading of the soil and obtain the quantity of lime required using the table given above and also calculate the LR in terms of other liming materials such as CaO , Ca(OH)_2 , etc.

- i. pH of the soil
- ii. Lime requirement

22.7 Expected behavioural outcomes :

The pupil will be able to :

- explain how acidity develops in soil;
- explain how acid soils are improved by liming;
- determine lime requirement;
- interpret the pH value in terms of lime requirement.

Grade

The teacher should evaluate the pupil for the above abilities.

22.8 Questions :

- i. What is an acid soil?
- ii. How acid soils are formed?
- iii. Is it necessary to lime an acid soil? If so, why?
- iv. What happens when an acid soil is shaken with extractant buffer?
- v. Name the various materials used for liming of acid soils.
- vi. Give the principle of the method of determining lime requirement of soils.
- vii. Give the composition of the extractant buffer employed.
- viii. Define the term lime requirement.
- ix. Differentiate between permanent and pH dependent charges on soil colloids.
- x. Up to what pH liming may be recommended?
- xi. What will be the effect of excessive liming (over-liming)?

23. Activity Unit

RECLAMATION OF SALINE, ALKALI AND SALINE-ALKALI SOILS

23.1 Instructional objectives :

The pupil should be able to :

- recall the extent of salt affected soils in India;
- differentiate between saline, alkali and saline-alkali soils;
- explain the reasons for formation of such soils;
- recall the steps required for reclamation of problem soils;
- work out the methodology to be adopted for reclamation of saline, alkali and saline-alkali soils.

23.2 Relevant information :

23.2.1 *Area under salt affected soils in India*

In India, salt affected soils (saline, alkali and saline-alkali) occupy an area of about 7 million hectares. Out of this, 4.5 million hectares occur in the states of Haryana, Punjab, Uttar Pradesh, Rajasthan and Gujarat.

23.2.2 *What is saline soil?*

Saline soils are those which contain large quantities of soluble salts and have generally white incrustation on the surface when dry. These soils have the electrical conductivity greater than 4 mmhos/cm in saturation extract, exchangeable sodium percentage (ESP) less than 15 and pH is below 8.5. In saline soils, sodium ions are generally one half of the soluble cations while chlorides and sulphates predominate among anions. Small quantities of bicarbonate and nitrate are also present.

23.2.3 *What is an alkali soil?*

Soils for which the term 'alkali' or 'sodic' is used contain high

quantities of exchangeable sodium *i.e.* , exchangeable sodium percentage (ESP) of the soil is more than 15 while the conductivity of the saturation extract is less than 4 mmohs/cm. These soils do not contain appreciable quantities of soluble salts. The pH value is generally higher than 8.5 and can exceed 10.5 depending upon the dominance of sodium carbonate.

23.2.4 What is saline-alkali soil?

These soils are intermediate in properties. The soils contain high ESP and high amount of soluble salts. Because of the influence of the latter the pH may not go very high.

23.2.5 Reasons for the formation of saline soils

- High water table with a high salt content
- High temperature promoting rapid loss of water from soil surface.
- Low rainfall and high evaporation rates.
- Excessive application of irrigation water.
- Seepage from canals and lateral channels.
- Irrigation with saline waters.
- Poor drainage.
- Use of salt producing fertilizers.

23.2.6 Technical requirements for effective reclamation

- Adequate drainage in the sub-soil region.
- Availability of sufficient amount of good quantity or low-salt water, for leaching out of excessive salts.
- Land levelling.
- Strong bunding of field plots for irrigation.
- Improved agronomic practices including cultivation of salt tolerant crops.

23.2.7 Salt tolerance of crops

The table below indicates relative tolerance of crops to salt*

High salt tolerance	Medium salt tolerance	Low salt tolerance
1	2	3
(10-16 mmhos/cm)	(4-10 mmhos/cm)	(Upto 4 mmhos/cm)
	<i>Field crops</i>	
Barley (grain)	Wheat	Bean (field)
Sugarcane	Mustard	Most pulses
Sugarbeet	Safflower	
Cotton	Castor	
<i>Dhaincha (Sesbania sp.)</i>	Rice	
	Jute	
	Sorghum (grain)	
	Maize	
	Flax	
	Sunflower	
	<i>Bajra (Pearl Millet)</i>	
	<i>Forage crops</i>	
Dub grass	Sweet clover	White clover
(<i>Cynodon sp.</i>)		
Rhodes grass	Lucerne	
	Berseem	
	Ryegrass	
	<i>Fruits</i>	
Date palm	Pomogranate	Pear
Coconut	Fig	Apple
	<i>Ber (Zizyphus sp.)</i>	Orange
	<i>Aonla</i>	Lemon
	Banana	
	<i>Vegetables</i>	
Beet	Tomato	Raddish
Asparagus	Broccoli	Celery
Spinach	Cabbage	Green beans
Turnip	Cauliflower	
	Lettuce	
	Sweet corn	
	Carrot	
	Potato	
	Onion	
	Peas	
	Squash & cucumber	

* Source : Richards, L.A. (Ed) *Diagnosis and Improvement of Saline & Alkali Soils*, Agri. Handbook No. 60 USDA (1954), partly modified for Indian conditions.

23.2.7 Relation between Exchangeable Sodium and Gypsum/Sulphur requirements :

Amounts of gypsum and sulphur required to replace indicated amounts of exchangeable sodium for reclamation purposes are given in the following table :

<i>Exchangeable sodium in m.e. per 100 g of soil</i>	<i>Gypsum t/ha for top 0-15 cm</i>	<i>Sulphur t/ha for 15 cm</i>
1.0	2.1	0.39
2.0	4.2	0.75
3.0	6.3	1.17
4.0	8.4	1.56
5.0	10.5	1.95
6.0	12.6	2.34
7.0	14.7	2.73
8.0	16.8	3.12
9.0	18.9	3.51
10.0	21.0	3.90

Adapted from : Agri. Handbook No. 60, USDA (1954).

23.3 Precautions :

Thorough knowledge of the following is essential before undertaking the job of reclamation:

- Salt content and ESP of soils.
- Salt concentration and composition of irrigation water. Only good quality water should be used.
- Salt distribution in root zone.
- Level of sub-soil water.
- Texture of the soil.
- Drainage conditions and absence of impervious layer in the sub-soil.
- Requirement of the amendments and their quality.
- Reclamation work should invariably be taken up during rainy season or prior to it if adequate water is available for the purpose.

23.4 Materials required :

a. Saline soil

- Good quality water
- Pair of bullocks with plough and other attachments like bund former etc.
- Solubridge (salt bridge)

- iv. Beaker
- v. Distilled water
- vi. Glass rod
- vii. Items needed for raising desired crops.

b. Alkali soil :

- i. Good quality water
- ii. Gypsum/sulphur
- iii. Materials required for the cultivation of *dhaincha*, rice and wheat crops
- iv. pH meter
- v. Beaker
- vi. Distilled water
- vii. Glass rod

c. Saline-alkali soils

Same as for the saline and alkali soils.

23.5a Procedure for reclamation of saline soils :

The procedure for reclamation of saline soils might vary a little according to local situations but on the whole following steps are to be followed for effective reclamation work :

- Level the plot as much as possible and divide it into sub-plots of convenient size based on gradient, if warranted.
- Dig a trench on one side of the plot in such a way that excess water can move out from the field. The trench should normally be 45 to 60 cm deep and width may vary, based on size of the plot (Fig.23.5a.1) and the number of trenches to be dug.
- Make a strong bund (30-45 cm high) around the plot and flood the area with good quality water.
- Plough to shallow depth in standing water for adequate mixing of soils and water and to ensure complete dissolution of soluble salts present in the soil layer.
- Allow the water to stand for two to three days.
- Remove thereafter the standing water of the plot by connecting the plot with the drainage channel or the trench. Ensure proper drainage of water. Impedence due to hard pan or impervious layer below to be removed.
- Add well decomposed organic residues or bulky manures and raise salt tolerant crops like *dhaincha*, rice, sugarcane.

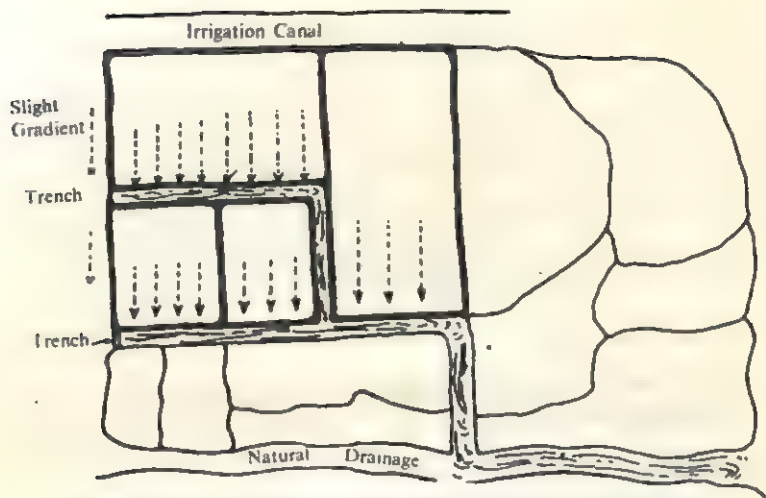


Fig. 23.5a.1 A LAYOUT PLAN FOR PROPER DRAINAGE

sugarbeet, barley, wheat, etc. based on soil test reports.

23.5b Procedure for reclamation of alkali and saline-alkali soils :

The steps for reclamation of alkali and saline-alkali soils will differ depending upon the severity of the problem and soil conditions but the following would be adequate in most situations :

- Level the plot and divide it into sub-plots of convenient size based on gradient and other characteristics.
- Dig a trench across the slope of the plot. The trench can be 60 to 75 cm deep and width may vary, according to the size of the plot and intensity of leaching with water.
- Make a strong bund (30-45 cm high) around the plot and 70-75 days prior to the onset of monsoon.
- Apply required quantity of gypsum/ pyrites as determined by gypsum requirement and mix it in the top 15 cm soil by 2 or 3 shallow ploughing followed by planking of the field.
- Flood the plot with good quality irrigation water.
- Allow the water to stand for two to three days.
- Remove the standing water of the plot by connecting the plot with the drainage channel or the trench.
- Wait till the soil of the plot comes in friable condition.
- Raise *dhaincha* for green manuring, if time permits.
- Plough down green *dhaincha* plants at the appropriate time (pre-flowering stage).

- Apply 20-25 kg of zinc sulphate per ha unless the available zinc status is high.
- Raise rice seedlings well in advance elsewhere for transplantation in the amendment treated/green manured plot. Then take all necessary steps required for good rice cultivation.
- Raise salt resistant variety of wheat or other salt tolerant crops during following *rabi* (winter) season by adopting improved agronomic practices.

23.6 Observations :

The pupil should take the readings separately for all the three types of salt-affected soils.

a. Saline soils

Analyse soils samples for electrical conductivity and note the difference in values before and after reclamation.

EC before reclamation = _____ mmhos/cm

EC after reclamation = _____ mmhos/cm

b. Alkali soils and saline-alkali soils

Analyse soil samples for EC and pH and note the difference in values before and after reclamation. Record quantity of gypsum/pyrites/sulphur required.

	Alkali	Saline-alkali soils
— EC before reclamation	= _____	_____ mmhos/cm
— pH before reclamation	= _____	_____
— EC after reclamation	= _____	_____ mmhos/cm
— pH after reclamation	= _____	_____

23.7 Expected behavioural outcomes :

The pupil will be able to :

- assess actual problems;
- undertake reclamation;
- determine EC and pH in soils as a follow-up measures;
- relate the reclamation work involved with the prevailing soil and environmental conditions.

The teacher should evaluate the pupil for the above abilities.

Grade

23.8 Questions :

- i. Name five states in the country which have maximum salt affected area.
- ii. Why is gypsum requirement increased with the rise of exchangeable sodium in the soil?
- iii. How will you clearly differentiate between a saline soil, and an alkali soil?
- iv. How does irrational use of irrigation water cause soil salinity alkalinity?
- v. How high water table influences formation of salt affected soils?
- vi. How drainage helps in reclamation of salt affected soils?
- vii. Why saline waters cannot be used for reclamation of salt affected soils?
- viii. What is the basic difference in approach in the reclamation of a saline and a sodic soil?
- ix. What is the effect of soil texture in the process of reclamation?
- x. When sub-soil drainage may be necessary?

24. Activity Unit

RECLAMATION OF ACID SOILS

24.1 Instructional objectives :

The pupil should be able to :

- recall the extent and distribution of acid soils in India.
- explain the factors causing acidity in soil;
- appreciate the need for reclamation of acid soils;
- distinguish various liming materials and their neutralizing value;
- explain the technique of reclamation of acid soils.

24.2 Relevant information :

24.2.1 Occurrence of acid soils

Acid soils occur in the high rainfall areas of the Western Ghats, Eastern Orissa, West Bengal, Kerala, Bihar, Assam, Tripura, Meghalaya, Manipur and Himachal Pradesh. It has been estimated that in India there are 26 million hectares of land with pH below 5.5 and 24 million ha have soils with pH between 5.6 and 6.5. Normal crop growth is not possible in acid soils except certain plants like tea and yields are generally very low. The use of lime to correct the acidic conditions prevailing in soils is mainly restricted to some experimental farms. It is necessary to demonstrate the benefits of liming on farmers' fields.

24.2.2 Causes of soil acidity

Soils become acidic due to one or more of the following reasons :

- The parent material from which the soil has been developed is acidic in nature. The most common example of such a parent material is granite rock having high percentage of silica.
- The lime and other bases have been either leached down or washed away from the root zone. On fallow silt loam under high rainfall the losses of bases as calcium carbonate

equivalent have been estimated as high as 970 kg per hectare per year.

- Depletion of lime and other bases are also due to their uptake by crops. The common field crops in India remove annually 50 to 350 kg of calcium carbonate equivalent per hectare from the soil.
- The continuous use of acid forming fertilizers make the soil acidic. On the basis of equivalent acidity per kg of N, ammonium sulphate is the most acid forming fertilizer and urea least.

24.2.3 Equivalent acidity

Equivalent acidity refers to the kg of CaCO_3 required to neutralize the acid produced in the soil from the quantity of fertilizer indicated. This is known as neutralizing value of calcium carbonate equivalent of liming materials.

24.2.4 Correction of soil acidity

Acidic conditions in soil can be corrected by adding liming materials. The amount needed will vary according to the nature of soil and degree of acidity. The function of lime is to neutralize the acidity developed by hydrogen ions and aluminium activity. Liming also supplies some plant nutrients like calcium and magnesium which are leached from the soil or removed by crops.

24.2.5 Lime requirement

The quantity of lime needed to neutralize soil acidity depends on the type, texture, organic matter content and buffering capacity of soils. Indiscriminate use of lime on coarse textured soils can lead to alkaline conditions resulting in deficiencies of iron, manganese and other micronutrients.

Limestone needed to increase the pH of the soil textural class by one pH unit is indicated in the table below:

<i>Soil texture</i>	<i>Limestone required to raise the pH value by one unit (t/ha)</i>
Sand	2.50
Sandy loam	3.75
Loam	5.00
Silt loam	6.25
Clay loam	7.50
Clay	8.25

24.2.6 Liming materials

Several materials such as dolomitic, calcitic limestones, burnt lime, hydrated lime, marl, lime sludge and slags are available. Most of the liming materials when reacting with acid soil lead to the formation of slightly dissociated carbonic acid (H_2CO_3).

- i. **CALCIUM OXIDE** : This is known as unslaked lime, burnt lime or quick lime, manufactured by roasting calcite limestone. It is a white powder difficult to handle. Complete mixing of calcium oxide in the soil is not easy.
- ii. **CALCIUM HYDROXIDE** : This is commonly known as slaked lime, hydrated lime or building lime. Like calcium oxide, it is a white powdery substance with some loose lumps and unpleasant to handle. It is prepared by hydrating calcium oxide. Much heat is generated and on completion of the reaction the material is dried and packed.
- iii. **CALCIUM AND MIXED CALCIUM—MAGNESIUM CARBONATES** : Crystalline calcium carbonate is termed as calcite or calcitic limestone. Calcium and magnesium carbonates occur in equimolecular proportions in dolomite. Other mixed deposits are said to be dolomitic limestones. The quality of crystalline limestone depends on the degree of impurities that they contain, such as clay.
- iv. **MARLS** : Marls are soft, unconsolidated deposits of calcium carbonate. They are frequently mixed with earth and are unusually quite moist. They are almost low in magnesium.
- v. **SLAG** : Three types of slags of the steel industry are important in agriculture. They are blast furnace slag, basic slag and electric furnace slag.
- vi. **LIME SLUDGE** : Some industrial wastes such as paper mill sludge are quite rich in lime and after drying etc. can be used as liming material.

The neutralizing values of calcium carbonate equivalent for various liming materials are given below:

<i>Material</i>	<i>Neutralizing value (%)</i>
CaO	179
Ca(OH) ₂	136
CaMg(CO ₃) ₂	109
CaCO ₃	100
Marl	70-90
Blast furnace slag	70-90
Basic slag	60-70
Electric furnace slag	65-80

24.2.7 Effectiveness of limestone in relation to fineness

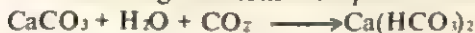
The degree of fineness is important because the speed with which the various materials react, depends on the surface of contact with the soil. If the particles of lime stone are coarse, the reaction will be slight which will increase with the fineness. The efficiency of applied limestone increases appreciably when it is ground to finer than 60-80 mesh (0.1-0.2 mm).

24.2.8 Application of lime

Particles of lime cannot move in the soil and consequently these must be placed where they are needed. Liming materials need to be worked well into the soil. This can be done during the preparation of the seed bed. If burnt or slacked lime is used liming must be done at least 2-3 weeks prior to seeding.

24.2.9 Reaction of limestone in soil

The following reactions take place in acid soil :



Thus the hydrogen ions in the soil solution react to form weakly dissociated water and the Ca^{++} is free to undergo exchange to displace the H^+ ions from the colloidal complex.

24.3 Precautions :

- Use homogenous soil sample for pH determination.
- Select locally available liming materials.

- Apply liming material in very fine form.
- Lime the soil well in advance of sowing (seeding).

24.4 Materials required :

- i. pH meter
- ii. Beaker
- iii. Glass rod
- iv. Liming material
- v. Plough
- vi. Harrow
- vii. Baskets

24.5 Procedure :

- Bring a representative sample of soil from the field to be reclaimed.
- Determine the pH of the soil in soil-water extract (1:2) as in Sub Unit 13b.
- Determine the lime requirement of the soil following the procedure given under Activity Unit 22.
- Select appropriate liming material.
- Calculate total quantity of the liming material after having known its neutralizing value of calcium carbonate equivalent.
- Spread uniformly half the quantity of lime on the field and plough/harrow it into the soil when the soil is in friable condition.
- Spread uniformly the remaining half of the liming material and mix it thoroughly by disking and harrowing. While mixing, the field should be in proper tilth.

24.6 Observations :

The pupil should take and record the readings.

- i. pH value of the soil before liming (reclamation)
- ii. pH value of the soil after reclamation

24.7 Expected behavioural outcomes:

The pupil will be able to:

- explain the causes and occurrences of acid soils

Grade

- in India;
- recall the various liming materials and their lime content;
 - explain the techniques for reclamation of acid soils.

The teacher should evaluate the pupil for the above abilities.

24.8 Questions:

- i. Name various liming materials.
- ii. What do you mean by neutralizing value of liming materials?
- iii. What do you mean by soil acidity?
- iv. What are the reasons for formation of acid soil?
- v. What are dolomitic limestones?
- vi. What are marls? What determines their value as liming materials?
- vii. What is the significance of fineness of the liming materials?
- viii. Why do acid soils become unfit for normal crop production?
- ix. How are the liming material applied in soils?
- x. When reclaiming acid soils to what pH value soil is it done?

25. Activity Unit

INTERPRETATION OF SOIL TEST DATA

25.1 Instructional objectives:

- The pupil should be able to:
- explain the importance of soil testing practice and programme;
 - have an idea of soil test methodology;
 - explain the significance of information needed for formulation of recommendations;
 - interpret soil test data and formulate fertilizer recommendations.

25.2 Relevant information:

25.2.1 *Soil Testing: What?*

Soil testing aims at making recommendations with regard to soil management practices in general and about use of manures and fertilizers in particular. Complete soil testing programme essentially consists of four basic steps as under:

- i. Collection of representative samples from the field;
- ii. Laboratory analysis;
- iii. Evaluation and calibration of soil tests; and
- iv. Interpretation of soil test data and drawing up of recommendations.

25.2.2 *Soil testing: Why?*

Farmers must be encouraged to increase their production and profits through proper and balanced use of fertilizers and soil amendments on their land. Soil testing programme mainly aims to fulfil this requirement.

25.2.3 Information needed for interpretation of soil test data :

Crop production is a complex process and actual yield is influenced by a number of factors. Soil analysis (testing provides a part of the information required. Consequently, an interpreter needs other particulars to make reliable and purposeful recommendations.

i. SOIL TEST DATA :

Routine analyses are done in the laboratory to determine pH, electrical conductivity, calcium carbonate (wherever present), lime and gypsum requirements (wherever needed), organic carbon and available nutrients (N, P and K), etc. Available micro nutrients are also analysed in selected samples in some laboratories.

ii. OTHER INFORMATION :

The following types of information are collected:

- Previous crops grown;
- Crop variety and population;
- Expected yield;
- Manurial history of the field;
- Availability of organic manures;
- Whether crop is irrigated or rainfed;
- Soil physical properties (particularly texture);
- Farmer's management capacity, time and method of application of fertilizers, etc. While it is desirable to have as much information as possible, it is likely that all of them may not be forthcoming. As such, one should be able to interpret the data on the basis of available information.

25.2.4 Formulation of recommendations for soil management practices

Mainly pH and EC measurements are used for this purpose. Following rating charts are made use of:

Rating on the basis of pH (1:2)

Type of soil	Soil reaction (pH)
Acidic	below 6.0
Normal	6.0—8.4
Tending to become alkali	8.5—9.0
Alkali	Above 9.0

Rating on the basis of EC (1:2)

Category	EC (millimhos/cm)
Normal	Below 1.0
Critical for germination	1.0—2.0
Critical for the growth of salt-sensitive crops	2.0—3.0
Injurious to most crops	Above 3.0

Rating of soil for garden plantation

Character	Citrus	Other plants
EC (mmhos/cm) at 25°C	Below 0.5	Below 1.0
Calcium carbonate (%)	Below 5.0	Below 10.0
pH	Below 8.5	upto 8.7 if EC is below 0.5 mmhos/cm

25.2.5 Use of soil amendments

No special management practices are needed for normal soils which are suitable for growing most of the crops. Use of soil amendments is recommended under following conditions:

- Liming is recommended for soils having pH below 6.4 (see Activity Unit 22 for lime requirement).
- Leaching of soluble salts is to be done for soil having high amounts of soluble salts (EC is above 400 millimhos/cm).
- Addition of gypsum and soil management practices are recommended for alkali soils (pH above 8.5). Amount of gypsum/pyrites to be used is determined by gypsum requirement (see Activity Unit 21). In the absence of such information, amount of gypsum can be decided on the basis of pH data of soil using the following rating chart.

Requirement of gypsum for improving different soils (t/ha)

<i>pH (1:2 soil water ratio)</i>	<i>Texture</i>		
	<i>Sandy loam</i>	<i>Loam</i>	<i>Clay loam</i>
8.5--9.0	Nil	2.47	4.94
9.0--9.5	2.47	4.94	7.41
9.5--10.0	4.94	7.41	9.88
Above 10.0	7.41	9.88	12.35

25.2.6 Suitability of crops in relation to pH range

Optimum ranges of soil reaction for the improvement of crops grown in India are given in the table 25.2.6. On this basis, crops to be grown can be selected. Furthermore, changes in soil pH by addition of amendments can be decided for crops to be grown for getting higher yields.

25.2.7 Approaches to fertilizer use

Two approaches viz. qualitative and quantitative are available to determine the amount of fertilizers needed for a particular crop. In addition to this, the rate of application is modified on the basis of previous crop, availability of organic manures, irrigation facility, management capacity of the farmer, etc.

i. Qualitative approach

In this, soil test values of nutrients are grouped into different categories (e.g. low, medium and high). This classification indicates that soils of low status markedly respond to added fertilizers while soils of high status often do not. Soils of medium status do not show definite response but to a variable extent. However, such broad grouping does not indicate the exact quantity of fertilizers to be added to get best economic yields. The soil testing laboratories develop a rating chart on the basis of crop, soil type and general response trend in the area. A typical rating chart is given on page 137 as an example which is formulated for wheat crop.

Table 25.2.6 : The most favourable range of soil reaction (pH) for different crops

<i>Crop</i>	<i>Botanical name</i>	<i>pH range</i>
Barley	<i>Hordeum vulgare</i>	6.5—8.0
Maize	<i>Zea mays</i>	5.5—7.5
Rice	<i>Oryza sativa</i>	5.0—8.5
Wheat	<i>Triticum aestivum</i>	6.0—7.5
Jowar (sorghum)	<i>Sorghum vulgare</i>	5.5—8.0
Cotton upland	<i>Gossypium hirsutum</i>	5.0—8.0
Linseed	<i>Linum usitatissimum</i>	5.0—7.0
Potato	<i>Solanum tuberosum</i>	4.8—6.5
Sweet potato	<i>Ipomoea batatas</i>	5.8—6.0
Rape seed	<i>Brassica napus</i>	6.0—8.5
Sugarcane	<i>Saccharum officinarum</i>	6.0—8.0
Tobacco	<i>Nicotiana tabacum</i>	5.5—7.5
Turnip	<i>Brassica rapa</i>	5.5—6.8
Banana	<i>Musa</i> sp.	6.0—7.5
Pineapple	<i>Ananas</i> sp.	5.0—6.5
Tea	<i>Thea sinensis</i>	4.0—5.5
Rubber	<i>Hevea brasiliensis</i>	3.5—8.0
Coconut palm	<i>Cocos nucifera</i>	6.0—7.5
Coffee	<i>Coffea</i> sp.	4.5—7.0
Beans, field	<i>Phaseolus vulgaris</i>	6.0—7.5
Beans, lima	<i>Phaseolus lunatus</i>	6.0—7.0
Clover, berseem	<i>Trifolium alexandrinum</i>	6.0—7.0
Cowpea	<i>Vigna sinensis</i>	5.0—6.5
Groundnut	<i>Arachis hypogaea</i>	5.3—8.0
Lucerne	<i>Medicago sativa</i>	6.2—7.8
Peas (canning & garden)	<i>Pisum sativum</i>	6.0—7.5
Grape	<i>Vitis vinifera</i>	6.0—8.0
Tomato	<i>Lycopersicon esculentum</i>	5.5—8.0
Cabbage	<i>Brassica oleracea</i>	5.5—8.0
lettuce	<i>Lactuca sativa</i>	5.5—8.0
Onion	<i>Allium cepa</i>	6.0—8.0

Rating chart

Crop : Wheat

Soil : All types

Nitrogen		Phosphorus		Potassium	
Category 'a'	Recommendations	Category 'b'	Recommendations	Category 'c'	Recommendations
	kg N/ha		kg P ₂ O ₅ /ha		kg K ₂ O/ha
0.00—0.25	125.0	0-10	62.5	0-100	30.0
0.26—0.37	112.5	11-15	50.0	101-150	25.0
0.38—0.50	100.0	16-20	50.0	151-300	15.0
0.51—0.60	87.5	21-25	42.5	above 300	Nil
0.61—0.70	75.0	26-37	37.5	—	—
0.71—0.75	62.5	38-50	30.0	—	—
above 0.75	62.5	above 50	25.0	—	—

Where :

Category 'a' indicates percentage of organic carbon.

Category 'b' indicates available phosphorus in kg P₂O₅/ha by Olsen's method

Category 'c' indicates available potassium in kg K₂O/ha.

ii. Quantitative approach

Here, yield of the crop is related to fertilizer responses and soil test values. Based on the availability of soils tests-crop response data, different levels of fertilizers can be recommended keeping in view the farmer's experience in using fertilizers and economic conditions. Application rate is to be suggested to enable the farmers to receive maximum return for each Rupee he invests on fertilizers. For progressive farmers, however, higher rate of application of fertilizer can be recommended to obtain greater gross profit per unit area.

25.2.8 Type, method and time of application of fertilizers

This information is obtained from the research and extension organizations of the region.

25.3 Precaution :

- Examine carefully all the informations provided by the farmer.

25.4 A case study :

The pupil should study the information given below for a hypothetical case.

Information available :

(a) Laboratory soil analysis report :

- i. pH—7.5 (1:2 soil water suspension)
- ii. EC—0.75 mmhos/cm (1:2 soil water ratio)
- iii. Organic carbon—0.65 per cent
- iv. Available phosphorus—7.2 Kg P_2O_5 /ha
- v. Available potassium—79.0 Kg K_2O /ha

(b) Information obtained with sample :

- i. Soil type—Black soil having clayey texture
 - ii. Crop to be planted—Wheat (Variety UP 301)
 - iii. Cropping history—Farmers has not been using fertilizers
 - iv. Availability of organic manures—No
 - v. Previous crop—Non leguminous
- (c) Availability research information

Research information	Nutrient status		
	Nitrogen	Phosphorus	Potassium
a. Critical level	Soils generally respond	16-18 Kg P_2O_5 /ha	100-150 Kg K_2O /ha
b. Application rate when below the critical level			
i. Maximum profit/ha	KgN/ha 137.5-162.5	Kg P_2O_5 /ha 40-50	Kg K_2O /ha 25-30
ii. Maximum return/Rupee	37.5- 50.0	20-25	12-15
iii. Minimum profitable dose	12.5- 20.0	10-12	6-8
c. Method of application	Split into ½ Basal ½ 30 days after sowing	All as basal placement	All as basal placement
d. Relative efficiency of fertilizer sources	All commonly available fertilizers which conform to the national quality control regulations (Fertilizer Quality Control Order) are suitable		

Note : Since the farmer is not well familiar with fertilizer use and has mostly limited resources, an application rate which can provide maximum return for the investment made on this account will be highly desirable.

Recommendations :

After studying the case, the pupil should formulate the fertilizer recommendations alongwith general observations about the case.

- i. About soil—normal/abnormal (salt affected)
- ii. About crops—All crops/selected crops; if selected, name them
- iii. About management practices—Routine/special (if special, what?/reclamation measures (if any)
- iv. Nitrogen— Kg/ha
- v. Method of application
(single/split dose; broadcast/placement)
 - Examine properly soil test data supplied or obtained.
 - Reduce rate of nitrogen application if previous crop was a legume by 12 and 25 Kg/ha for rainfed and irrigated areas, respectively.
 - Reduce the rate of application of nitrogen depending upon the quantity and type of organic matter available.
- vi. Phosphorus — Kg/ha
- vii. Method of application
- viii. Potassium — Kg/ha
- ix. Method of application

25.5 Expected behavioural outcomes:

The pupil will be able to:

- rate soils under various categories on the basis of soil test data;
- suggest suitable recommendations for soil management practices and reclamation measures if warranted by soil test;
- make fertilizer recommendations on the basis of soil test data (for a given hypothetical case).

The teacher should evaluate the pupil for the above abilities.

Grade

25.6 Questions:

- i. What is soil testing?
- ii. Why is soil testing necessary?
- iii. What do you understand by 'critical level'?
- iv. What are the implications of maximum and minimum profitable doses of fertilizers?
- v. Why do we need information other than soil analysis report for formulation of recommendations for soil management and fertilizer use?
- vi. Under which conditions the use of soil amendments and special management practices are recommended?
- vii. Why is knowledge of the previous crop needed in formulation of fertilizer doses?
- viii. Are the soil physical properties also to be considered?
- ix. Why irrigation availability should be taken into consideration while making fertilizer recommendations?
- x. What are the limitations/shortcomings of soil testing?

Appendix-I

LIST OF CHEMICALS

<i>Sl. No.</i>	<i>Item</i>	<i>Quantity</i>	<i>Approx. cost Rs.</i>
1.	Sodium hexametaphosphate	1 Kg.	40
2.	Hydrogen peroxide 6% (20 volume)	4 l	120
3.	Amyl alcohol	500 ml	30
4.	Rectified spirit	10 l	100
5.	Hydrochloric acid (pure)	2.5 l	50
6.	Phenolphthalein indicator	100 g	10
7.	Methyl red indicator	100 g	10
8.	Sulphuric acid (extra pure or analytical grade)	5 l	150
9.	Ferrous ammonium sulphate	1 Kg	30
10.	Potassium dichromate (analytical grade)	500 g	40
11.	Diphenylamine indicator	50 g	10
12.	Phosphoric acid (CR)	1 l	50
13.	Sodium fluoride	500 g	20
14.	Potassium permanganate	500 g	20
15.	Sodium hydroxide (pellets)	1 Kg	25
16.	Sodium bicarbonate	2 Kg	25
17.	Activated charcoal-Darco G-60	1 Kg	120
18.	Ammonium molybdate (ER/ AR)	100 g	60
19.	Stannous chloride	100 g	60
20.	Ammonium acetate	2 Kg	60
21.	Liquid ammonia	2 l	30
22.	Ammonium chloride	500 g	10
23.	Acetic acid, glacial	2 l	30
24.	Potassium chloride (EP)	500 g	15
25.	Calcium sulphate	500 g	20
26.	Eriochrome black 'T' indicator	100 g	20
27.	EDTA di-sodium salt	100 g	20
28.	Calcium chloride (AR/EP)	500 g	10
29.	Paranitrophenol	100 g	20
30.	Calcium acetate	100 g	20
31.	Buffer tablets pH 4.0	20	30
	" 7.0	20	30

	" 9.2	20	30
32.	Methanol	2 l.	30
33.	Ammonium purpurate	100 g	20
34.	Copper sulphate	500 g	10
35.	Universal indicator	100 ml	25
36.	pH indicator solutions (eight in number)	100 ml each	200
37.	Triethanolamine	500 ml	30
38.	Barium sulphate (EP)	500 g	35
39.	Silver nitrate	25 g	50
40.	Barium chloride	500 g	15
41.	Potassium chromate	250 g	20
42.	Sodium chloride (EP)	500 g	20
43.	Magnesium chloride (EP)	100 g	10
44.	Calcium carbonate (EP/AR)	500 g	35
45.	Nitric acid (CP)	1 l	20
46.	Calcium chloride (fused)	2 Kg	30
47.	Potassium dihydrogen ortho phosphate (AR)	250 g	25
48.	Potassium dihydrogen phthalate (AR)	250 g	30

Grades of reagents :

AR : Analytical reagent

EP : Extra pure

CP : Chemically pure (if not otherwise stated)

Appendix-II

LIST OF GLASS-WARES

<i>Sl. No.</i>	<i>Item</i>	<i>Quantity</i>	<i>Approx cost Rs.</i>
1.	Watch glass 10 cm dia.	12	60
	15 cm dia.	6	30
2.	Glass rod 4-5 mm dia.	1 Kg	30
3.	Reagent bottles-----		
	100 ml	10	40
	250 ml	10	50
	500 ml	10	80
	1 litre	10	150
	2.5 litre	5	100
4.	Beaker-----		
	100 ml	30	200
	250 ml	10	150
	500 ml	10	250
	600 ml	6	200
	1000 ml	2	80
5.	Measuring cylinder-----		
	50 ml	3	20
	100 ml	3	30
	250 ml	3	50
	500 ml	3	60
	1000 ml	3	100
	1000 ml	6	240
	(stoppered)		
6.	Volumetric flask-----		
	25 ml	20	200
	50 ml	10	100
	100 ml	10	100
	250 ml	3	160
	500 ml	3	60
	1000 ml	3	90
7.	Desiccator 8" diameter	2	200
8.	Specific gravity bottle (pycnometer)	6	90
9.	Pipette-----		
	2 ml	3	15
	5 ml	6	30
	10 ml	6	60
	25 ml	3	60
	50 ml	2	50

10.	Glass funnel 4"		10	60
	6"		5	40
11.	Distillation set all glass	1 set		500
12.	Burette	50 ml	6	300
13.	Conical flask -----	100 ml	6	60
		150 ml	6	60
		250 ml	12	240
		500 ml	10	200
		1000 ml	3	75
14.	Kjeldahl digestion flask 800 ml capacity (Borosil/ Corning)		6	150
15.	Glass tubing 5-10 mm dia.		2 Kg	40
16.	Winchester bottle -----	2 litre cap.	6	120
		3 litre cap.	6	60
17.	Filtering flask -----	500 ml cap.	6	90
		1000 ml cap.	2	100
18.	Test tube 25 mm x 150 mm		100	200
19.	Evaporating dish	50 ml	4	60

Appendix-III

LIST OF LABORATORY INSTRUMENTS/ EQUIPMENT

<i>Sl. No.</i>	<i>Item</i>	<i>Quantity</i>	<i>Approx. cost (Rs.)</i>
1.	Hot plate 12" x 18"	1	600
2.	Sand bath on stand	1	50
3.	Water bath 12" x 18" with 12 holes	1	800
4.	Water still (distilled water plant) 4-6 litre capacity/hour	1	1200
5.	Chemical balance	1	600
6.	Physical balance	2	750
7.	Triple beam balance	1	200
8.	Beranger balance 5 Kg capacity	1	250
9.	Analytical weight box 100 g capacity	2	240
10.	Physical weight box 50 g to 500 g	2	200
11.	Sieves brass, 8" diameter 5 mm, 2 mm, 1 mm, 0.5 mm, 0.2 mm, 0.1 mm	1 each	600
12.	Oven 60 cm x 45 cm x 45 cm	1	1800
13.	Soil stirrer	1	800
14.	Stop watch	1	250
15.	pH meter with glass electrodes	1	2500
16.	Conductivity bridge (solubridge)	1	2000
17.	Photo-electric colorimeter, double cell	1	6000
18.	Flame photometer complete with air compressor	1	15000
19.	Bouyoucus soil hydrometer	3	300
20.	Liquid petroleum gas (L.P.G.) cylinder and hot plate	1	1800
21.	Bunsen burners for L.P.G.	4	200
22.	End over end (horizontal) shaker	1	1200
23.	Nitrogen (Kjeldahl) digestion and distillation units (set of six each)	1 set each	2000
24.	Vacuum pump	1	1200

Appendix-IV

LIST OF MISCELLANEOUS ITEMS

<i>Sl. No.</i>	<i>Item</i>	<i>Quantity</i>	<i>Approx. cost Rs.</i>
1.	Thermometer		
	0-100° C	3	60
	0-250° C	2	40
2.	Wash bottle polythene 500 ml	20	150
3.	Moisture box (aluminium) 6 cm dia. 5 cm height	20	100
4.	Core sampler with hammer	2	600
5.	Vernier caliper	2	30
6.	Spatulla 8"	3	30
	4"	3	15
	2"	3	10
7.	Tube auger 1½" dia, 50 cm long	3	150
8.	Post hole auger 2½"	1 set	100
9.	Keen's Box	6	120
10.	Filter paper ordinary	250 sheets	250
11.	Filter paper Whatman No. 1	100 sheets	500
12.	Tray 8" x 12" glass/polythene	3	60
13.	Trays 10" x 15" wooden	3	45
14.	Infiltrometer rings 30 cm and 50 cm dia.	2 sets	250
15.	Driving plate for infiltrometer rings	2	60
16.	Sample jars 2 Kg capacity with polythene	20	60
17.	Plastic bottles 100 ml capacity	50	100
18.	Porcelain dish 4"	10	50
	Porcelain dish 8"	6	120
19.	Filter paper Whatman No. 40 11 cm	2 packets	250
	Filter paper Whatman No. 42 11 cm	1 packet	125
20.	Plastic reagent bottles stoppered 250 ml	20	100
	500 ml	10	50
21.	Plastic tubing 5 mm—10 mm	30 m	60
22.	Rubber tubing 5-10 mm	10 m	40
23.	Glass marking pencil	24	30

24.	Glass tube cutter	1	60
25.	Triangular file	1	15
26.	Carbuoys 35 litre	2	150
27.	Polythene carbuoys 22 litre	6	180
28.	Buchner funnel 10 cm	4	80
	Buchner funnel 15 cm	4	100
29.	Rubber adopters	6	15
30.	Scissors, screw driver/spanner set	1 set each	100
31.	Tongs	6	30
32.	Knife 5-6"	2	10
33.	Pipette stand-Burette stand	6 each	120
34.	Test tube stand	10	100
35.	Filter stand wooden/plastic	10	100
36.	Munsell colour chart	1	250
37.	Buckets, polythene different sizes	6	120
38.	Basket polythene different sizes	3	60
39.	Soil sampling tools		
	Spade	2	30
	Pick-axe	1	20
	Khurpi	3	15
40.	Set of weights 100 gm to 5 Kg	1	60
41.	Hand gloves	3 pairs	30
42.	Cloth bags 9" x 12"	100	300
43.	Polythene bags 6" x 9", 9" x 12"	5 Kg	120
44.	Carton boxes for soil samples	500	250
45.	Labels (tag type)	5000	100
46.	Gummed label books	6	30
47.	Tape, 30 m	1	50
48.	Metre rod	6	30
49.	Metallic scale 12"	3	15
50.	Nylon chord 50 m	1 roll	100
51.	Plastic/cotton thread	6 rolls	30
52.	Rubber corks different sizes	120	50
53.	Velvet corks different sizes	150	50
54.	Wire gauge	30	20
55.	Retort stand iron	6	90
56.	Clamps & box heads	12	60
57.	Mortar & pestle, wooden	2 sets	80

58.	Asbestos sheet	6	120
59.	Filter pump (water tap type)	6	60
60.	White (porcelain) tiles 15 cm X 15 cm glared	10	30
61.	Tripod stand	10	50
62.	Spirit lamp/burner	3	30
63.	Towels	2	30
64.	Dusters	6	30
65.	Cleaning powder	5 Kg	20
66.	Graph paper	1 book (100sheets)	20
67.	Vacuum greese	1 jar	20

Appendix-V

LIST OF THE CONTRIBUTORS AND REVIEWERS

Contributors :

1. Dr. T.N. Chaudhary
Senior Scientist
Division of Agri. Physics, IARI
New Delhi-110012.
2. Dr. S.N. Sharma
Assistant Professor
Deptt. of Soil Sciences
Rajasthan College of Agriculture
Udaipur, Rajasthan.
3. Dr. B.N. Swami
Assistant Professor
Deptt. of Soil Sciences
Rajasthan College of Agriculture
Udaipur, Rajasthan.
4. Dr. A.K. Dhote
Lecturer, D.V.E.
NCERT, Sri Aurobindo Marg
New Delhi-110016.
5. Dr. A.K. Sacheti
Reader, D.V.E.
NCERT, Sri Aurobindo Marg
New Delhi-110016.

Reviewers

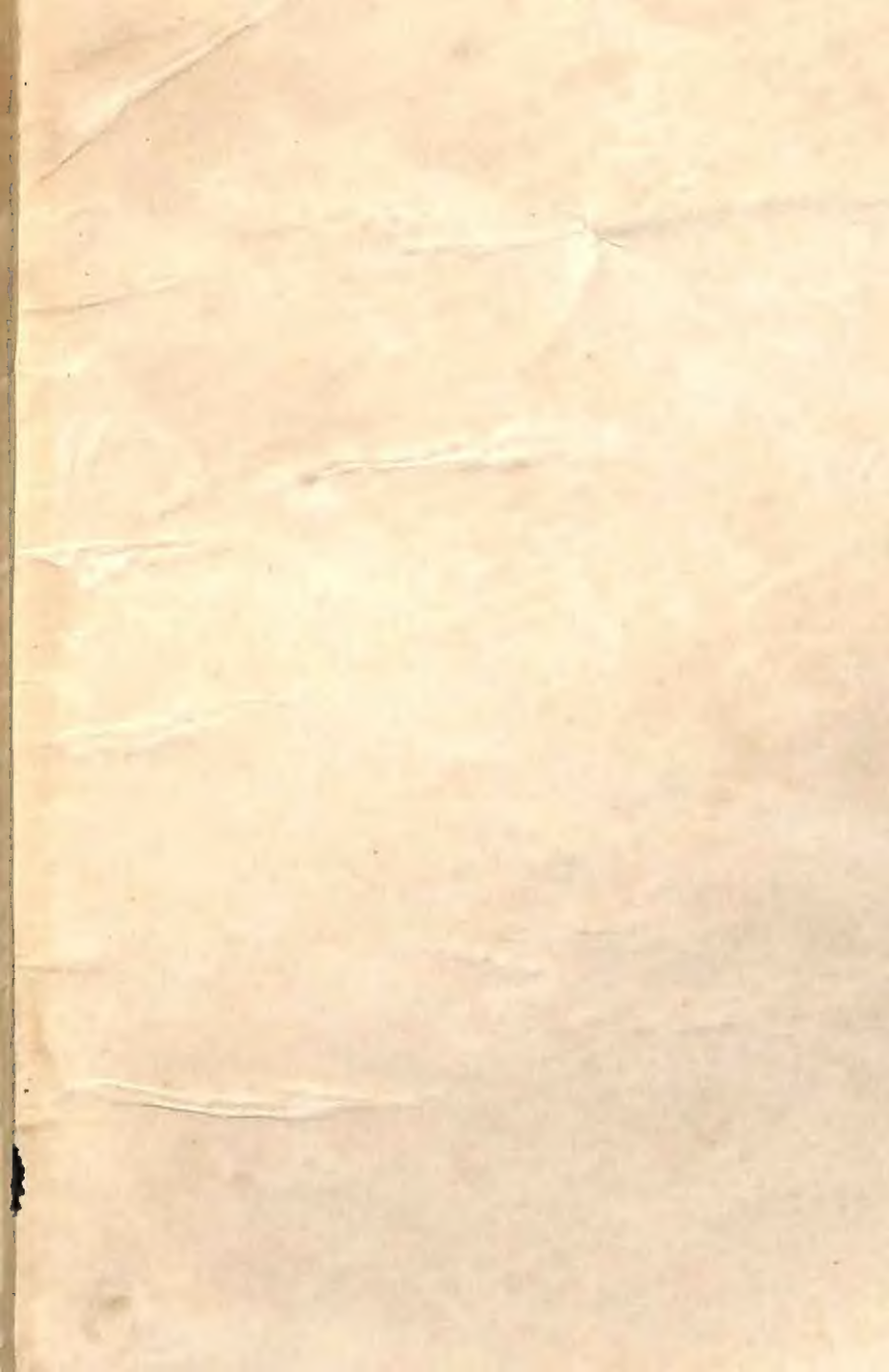
1. Dr. Sant Singh
Emeritus Scientist (ICAR)
Deptt. of Soil Science & Agri. Chemistry
Institute of Agri. Sciences
B.H.U. Varanasi-221005
2. Dr. A.B. Ghosh
Senior Soil Scientist
Division of Soil Science & Agri. Chemistry.
I.A.R.I., New Delhi-110012.

3. Dr. U.S. Sreeramulu
Professor & Head
Department of Soil Sciences & Agri. Chemistry
Agricultural College and Res. Institute.
Madurai, Tamil Nadu
4. Dr. P.B. Deshpandey
Professor of Chemistry & Soils
Agricultural College, Hebbal
Bangalore-560024.
5. Dr. B.L. Jain
Scientist S-3,
C.A.Z.R.I., Regional Station
Pali, Rajasthan.











राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING